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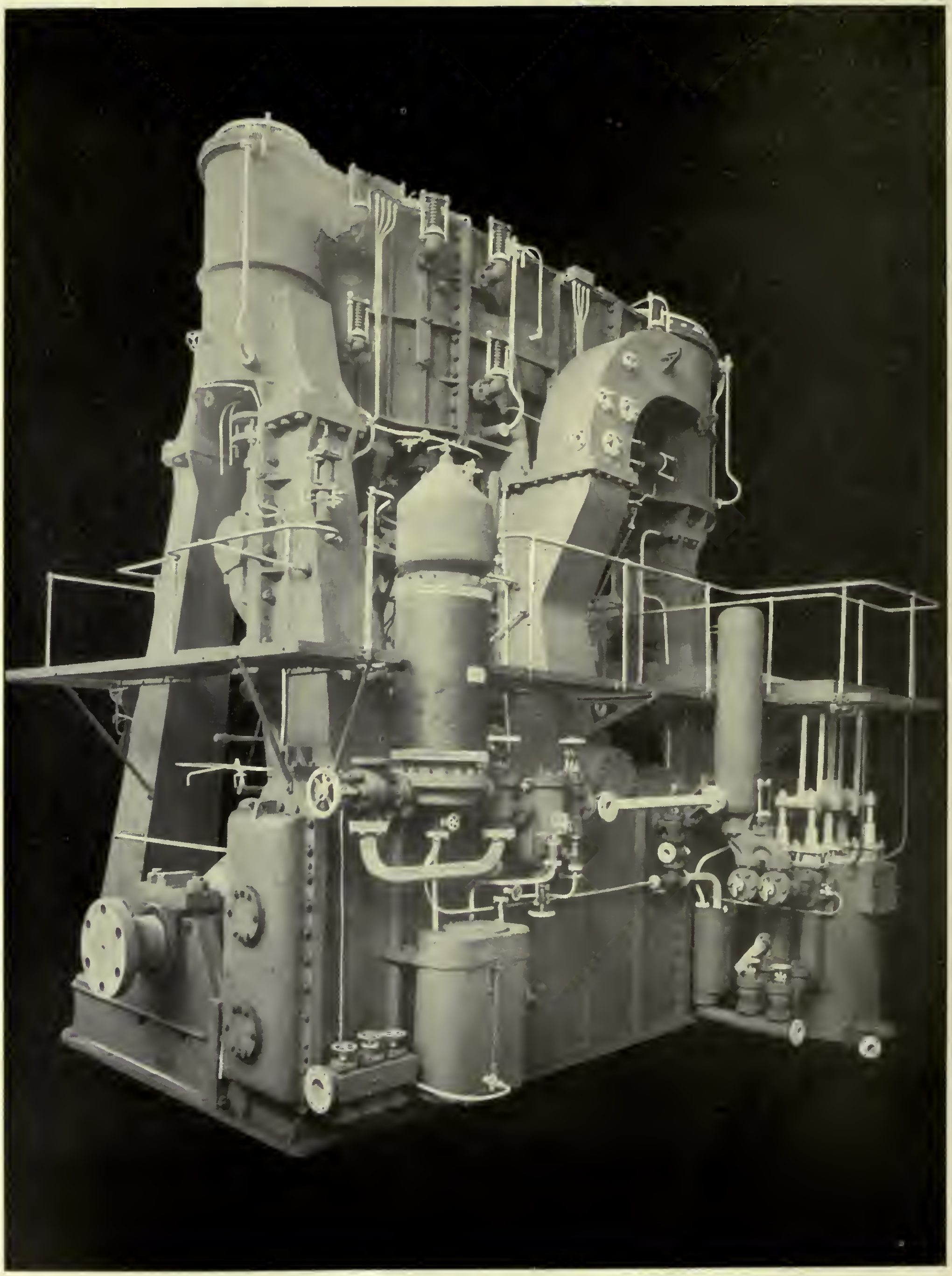
MODERN ENGINES
AND
POWER GENERATORS



Back View of Triple-Expansion Three-Cylinder Marine Engine.

Frontispiece.]

MODERN ENGINES
AND
POWER GENERATORS

A PRACTICAL WORK ON PRIME MOVERS AND THE TRANSMISSION OF POWER STEAM, ELECTRIC, WATER, AND HOT AIR

BY

RANKIN KENNEDY, C.E.

AUTHOR OF
"ELECTRICAL INSTALLATIONS" "ELECTRICAL DISTRIBUTION BY ALTERNATING CURRENTS AND TRANSFORMERS" "PHOTOGRAPHIC AND OPTICAL ELECTRIC LAMPS" AND NUMEROUS SCIENTIFIC ARTICLES AND PAPERS ON MECHANICAL AND ELECTRICAL ENGINEERING

WITH MANY HUNDRED ILLUSTRATIONS

VOL. V.

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PREFACE TO VOLUME V

THIS Volume deals with marine engines, and turbines for motor ships and motor boats. At present shipbuilders have not arrived at the use of internal combustion engines beyond small oil or petrol engines for small craft, and that mostly for pleasure and sporting purposes. The steam turbine remains the most modern type of marine engine of any considerable power, and for high speeds.

The combined reciprocating and turbine steam engine may prove suitable for smaller powers and lower speed vessels carrying cargo, especially in conjunction with steam superheaters. And a similar combination of an internal combustion engine with cylinders and pistons and a turbine utilising the exhaust gases has been proposed, and described; it promises well for marine propulsion. In fact, marine engineering is at present in a transitory state, leading to the internal combustion of the fuel and the abolition of steam and its generators.

Locomotives form the concluding portion of the Volume — steam, petrol, and electric examples being given.

RANKIN KENNEDY.

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MODERN ENGINES AND POWER GENERATORS

CHAPTER I

HIGH-SPEED ENGINES

PETER BROTHERHOOD'S HIGH-SPEED ENGINE

The engine here illustrated is one supplied to the Royal Navy for electric generators. It was made for low pressure, that being only 60 lbs. per square inch. Similar engines for the new first-class cruisers have to carry the full load with 125 lbs. steam when exhausting against 25 lbs. gauge pressure in the exhaust pipes. For this reason the ratio of the low-pressure cylinder to the high-pressure cylinder is lower than usual. The diameter of the low-pressure cylinder is 20 inch, the stroke being 8 inches. At a speed of 450 revolutions the horse-power is 150 indicated.

The general arrangement is shown in the illustrations. Fig. 1 is a longitudinal section; Fig. 2, a cross section; Fig. 4, details of the governor; Fig. 5, the throttle valve; and Fig. 3, a photographic view of the engine.

Piston valves with removable liners are fitted to all cylinders, the high-pressure valve rings being solid, and ground and lapped. The low-pressure valves have spring rings of cast iron, which are ground to standard size. The pistons are of forged steel. The piston rings are of special Admiralty type, and are of phosphor-bronze; the weight of the pistons is adjusted to give balance to the moving parts. The piston rods are of forged steel, the rods being finished true by machine grinding, in order to work well with metallic packing. The pistons are secured by steel nuts on cone and parallel fitting parts on the rods. The connecting rods are of the marine type, forked at the cross-head end, and fitted with hardened and ground pins. The crank shaft is of forged steel, and is annealed after rough turning. The main bearings and crank pin brasses are of gun-metal, lined with white metal, the cross-head brasses being of phosphor-bronze. Duplicate oil strainers are fitted, and these can be removed for cleaning while the engine is running. Top wiper glands are fitted where the piston and valve rods pass through the engine casing; whilst circular oil throwers are provided to prevent oil passing along the shaft. Provision is made for the free circulation of air to keep the parts cool.

Special attention has been paid to the governing, which is designed to meet the exacting demands of the specification in regard to control, and also to give good results

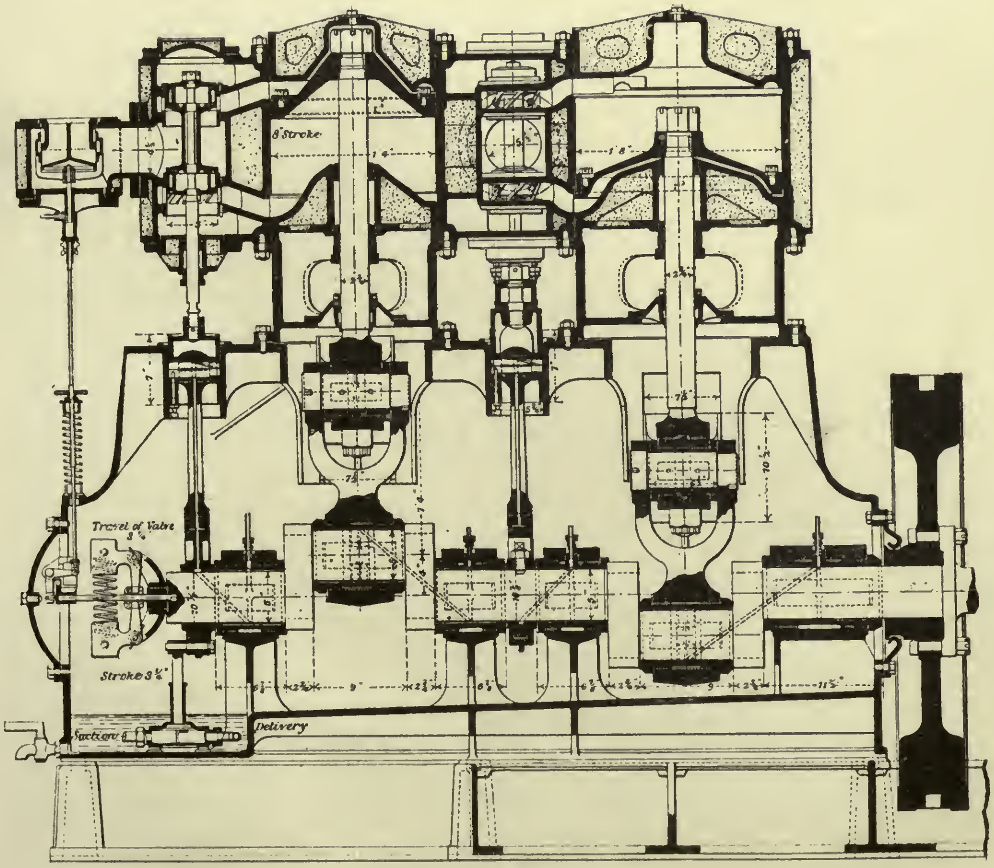

8 Stroke
Travel of Valve 3¼
Stroke 3¼"
Suction
Delivery
10½"
11½"
9"
9"

FIG. 1.—Longitudinal Section.

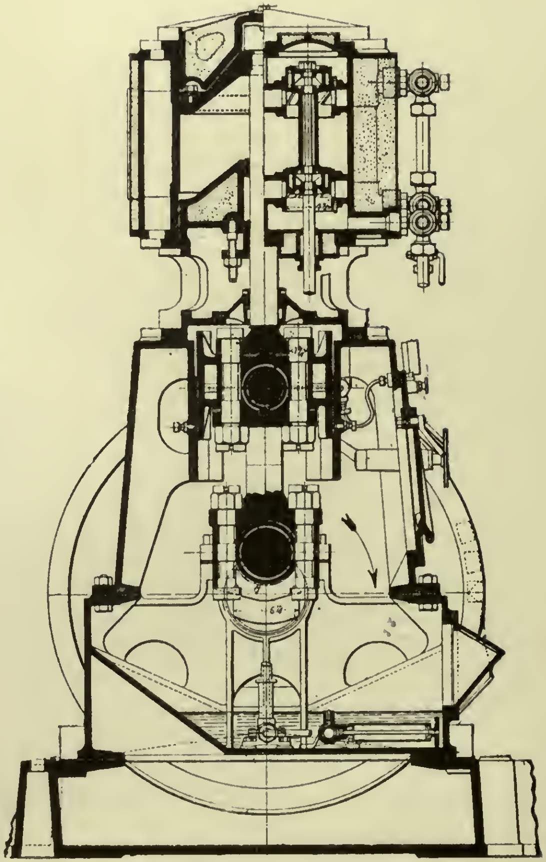


FIG. 2.—Transverse Section.

Brotherhood's High-Speed Engine.

in unskilled hands, even after prolonged use of the engine. The governor is of the throttling type, and the revolving weights are of large size in order to give considerable power. To avoid oscillation, due to the relatively large inertia of the weights, their movement from the maximum to the minimum speed is small. The resultant forces, due to the two springs attached to them, act through the centres of mass of the balls, thus minimising the pressures on the pin joints. The external spring (the load on which is variable while running, in order to give means of adjustment of speed) usually provides about one-third of the total spring load. The central spindle, which transmits

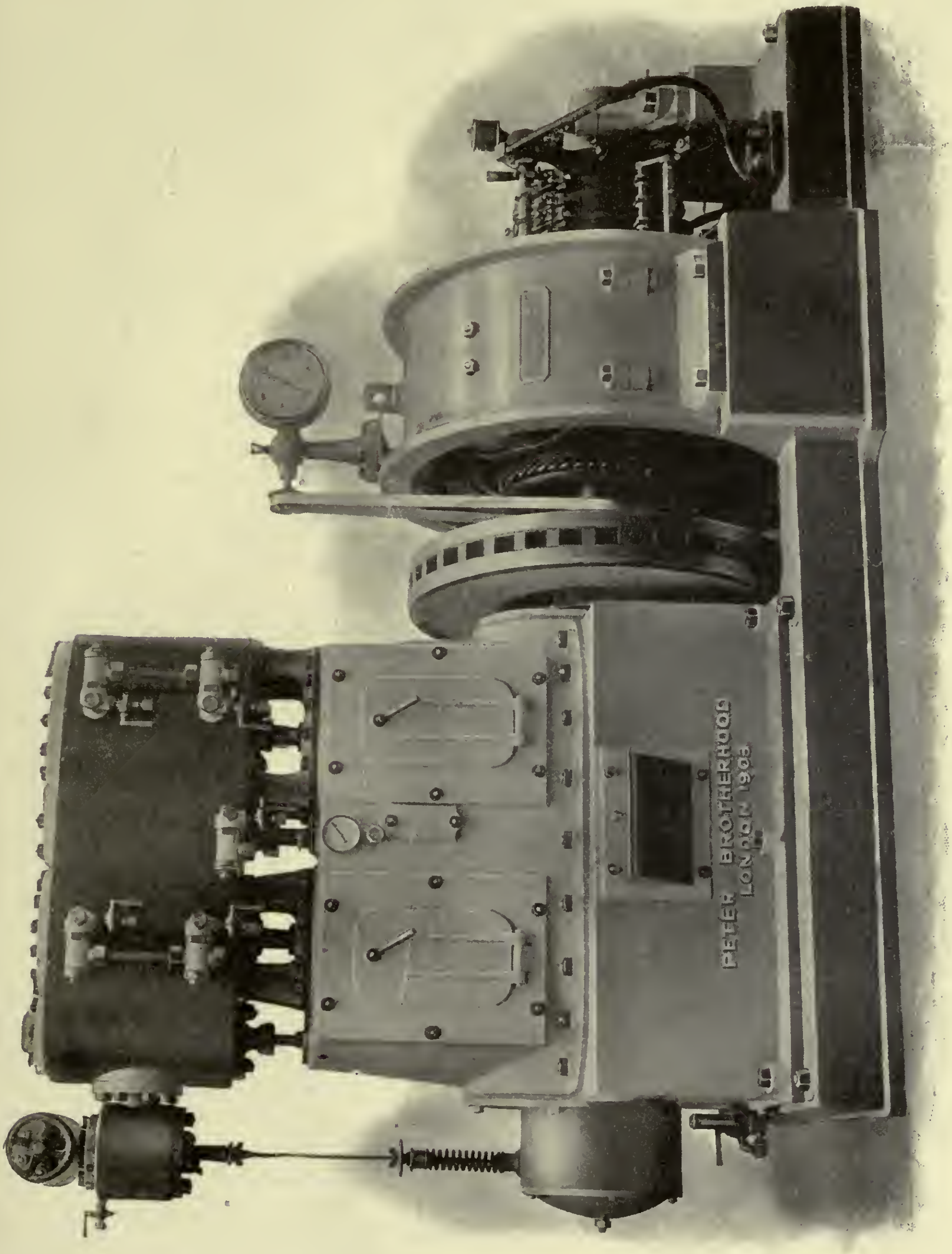


Fig. 3.—Brotherhood's High-Speed Engine.

the motion of the balls to the valve, is of steel, and has hardened steel rollers to reduce friction at the connection with the ball arms. At the other end the spindle is hardened, and works in a small phosphor-bronze sleeve, the end of this sleeve being pointed, and bearing against the bell crank attached to the governor valve rod. The upper part of the sleeve forms an oil cup, constantly filled by the oil thrown from the moving parts of the engine. Oil is led to the centre of the revolving spindle, and moves radially outwards as the spindle revolves. The sleeve and the spindle are the only parts subjected to considerable motion, and the former is readily renewable.

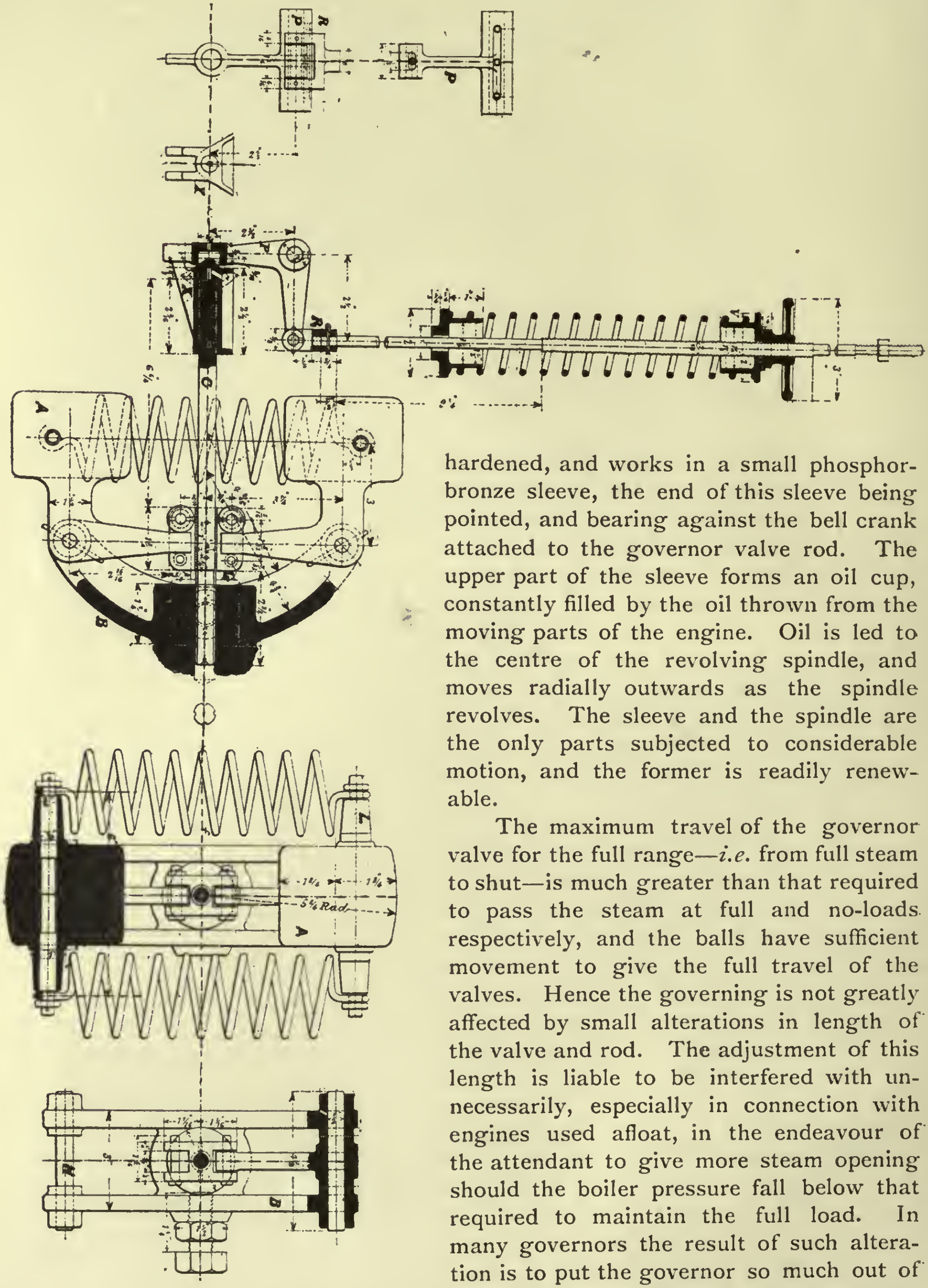


FIG. 4.—Governor Gear of Brotherhood's Engine.

The maximum travel of the governor valve for the full range—*i.e.* from full steam to shut—is much greater than that required to pass the steam at full and no-loads respectively, and the balls have sufficient movement to give the full travel of the valves. Hence the governing is not greatly affected by small alterations in length of the valve and rod. The adjustment of this length is liable to be interfered with unnecessarily, especially in connection with engines used afloat, in the endeavour of the attendant to give more steam opening should the boiler pressure fall below that required to maintain the full load. In many governors the result of such alteration is to put the governor so much out of adjustment as to lead to racing when all load is removed. This governor is designed to prevent this happening, for the normal valve opening may be very largely exceeded without preventing the closing of the valve by the governor when the load is removed. The normal travel being small, wear of the valve is reduced, and, at the same time, owing to the large valve lap, there is a large range for compensating for wear. The use of heavy balls gives great power without setting up inertia troubles, as the swinging movements are too slight for any appreciable momentum to be attained ; the time required for performing the swing being very small, the momentary variations of speed are minimised.

The dynamos for these sets are the ordinary 4-pole compound type of 100 kilowatts capacity, as made by the Thames Electrical Engineering Works. They have an output of 450 to 475 ampères at 220 volts. The armatures are of a form specially constructed for traction work, being former wound, with slotted core. The commutator is of large brush area, and is fitted with carbon brushes. The end bearing has ring lubrication.

The governing is certainly very close, the whole load being suddenly removed and reapplied with small variation. In the table are given the results of a few governor tests, taken from recent official trials of these engines, which have been supplied by Mr. Brotherhood.

RESULTS OF A FEW RECENT TESTS OF GOVERNORS OF BROTHERHOOD'S ENCLOSED HIGH-SPEED ENGINES.

Order Number.	Steady Speed with Full Load.	Steady Speed with No Load.	Momentary Increase or Fly-up when Load was suddenly removed.	Percentage of Control.
	Revs. per min.	Revs. per min.	Revs. per min.	
1452	435	440	443	1.15
1452	450	456	460	1.4
1260	405	411	426	1.5
1260	388	395	408	1.8
1260	399	403	418	1.0
1260	404	410	415	1.5
1311	387	398	410	2.9
1311	392	399	412	1.8
1260	392	398	400	1.5

In addition to these tests the governors were tested for range of control. The speeds could be varied within a limit of 15 per cent. above and below normal speed without change of spring, the percentage of control being under 2 per cent. in all cases throughout the entire range.

Special attention has been given to lubrication in these engines. The oil is supplied under pressure to all working parts by a small valveless oil pump driven directly from the crank shaft. The oil is drawn from the reservoir at the end of the crank casing through duplicate strainers. These are so arranged that either may be readily and conveniently removed, cleaned, and replaced whilst the engine is running without interfering with the oil supply, or allowing any unstrained oil to reach the bearings. The oil is delivered from the pump to a bronze distributor, from whence separate pipes lead to all the moving parts. A pressure gauge is fitted on the front of the engine to indicate the oil pressure maintained ; and a relief valve with external regulating handle is also fitted to allow of variation in adjustment, if necessary, owing to change of density or viscosity of the

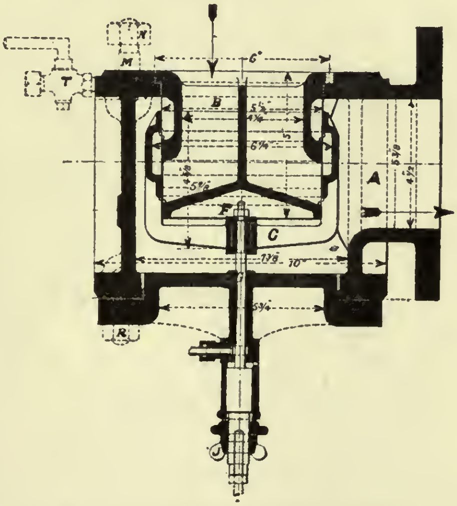


FIG. 5.—Throttle Governor Valve.

oil used. The oil pump is single acting, but the arrangements provide for constant oil pressure throughout the entire revolution of the crank shaft. To ensure this, a part of the oil discharged during the delivery stroke of the pump is stored and supplied to the bearings, etc., whilst the pump is refilling. This provision is designed to ensure efficient and uniform lubrication of the whole of the working surfaces, and to prevent vibration and injury to the pressure gauge and oil-distributing pipes.

BELLISS & MORCOM HIGH-SPEED ENGINES

Reference has already been made to the argument in favour of high-speed engines based on this firm's experience, and experience large and varied.

The Belliss patent quick-revolution self-lubricating engines are made in all the usual varieties—simple (single and double-cylinder), compound, and triple,—all being fitted with their patent system of forced lubrication, by which they are able to obtain, with an ordinary double-acting engine, all the advantages of quiet running at high speeds of revolution which have been claimed for single-acting engines, and, at the same time, have got rid of the grave defects which have frequently caused the single-acting engines to be given up under circumstances where the very best supervision could not be given.

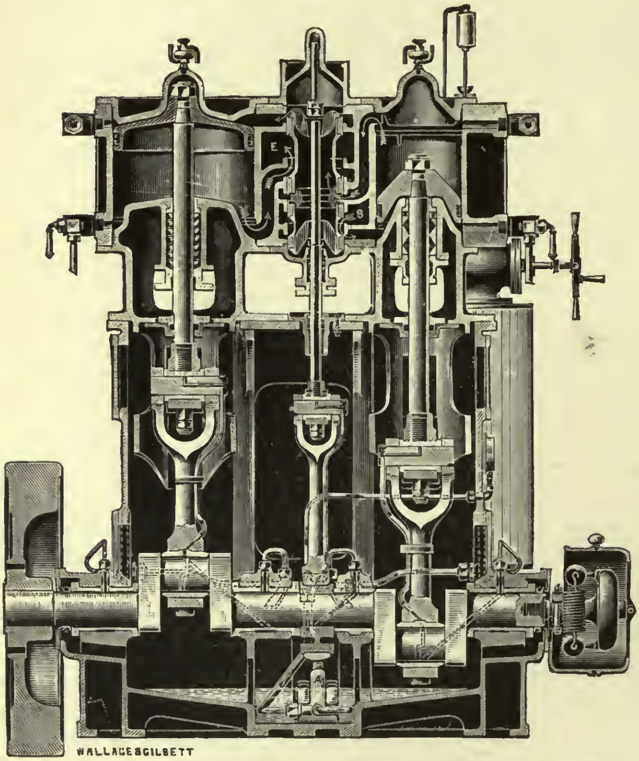


FIG. 6.—Longitudinal Section.

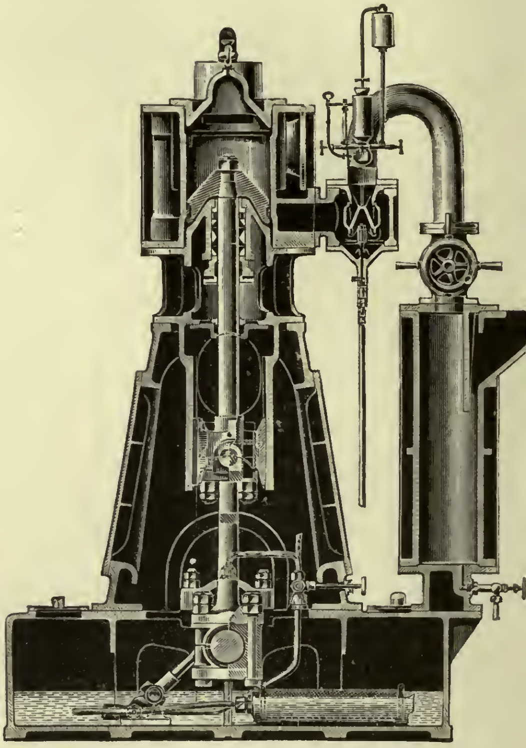


FIG. 7.—Transverse Section.

Belliss & Morcom Compound High-Speed Engine.

On this system oil is supplied to all the bearings by means of a simple pump, without valve or packing, discharging at a pressure of 10 to 20 lbs. per square inch, through a specially arranged system of oil channels. The oil escaping from the bearings drains into the crank pit, to be used over again. The system of lubrication was originated in 1890, and since that time worked out in all its details.

The engine, as shown in the illustrations, is of the ordinary double-acting type, with a casing surrounding the working parts to prevent dirt getting at them, and to permit of the forced lubrication without waste of oil.

The double action of the engine permits the film of oil at this pressure to get thoroughly between the working journals and brasses, keeping them apart and preventing any wear or chance of knocking with any load. Engines having a "constant thrust" cannot possibly get so effective a system of lubrication to the working surfaces. The casing is fitted with a door at back, and the whole front can be removed in a few minutes, if necessary, to overhaul the working parts. As the cranks of these engines are never immersed in oil there is no splash as with the ordinary closed-in machinery, and the engines can be run with the doors at the back open, if desired, for inspection.

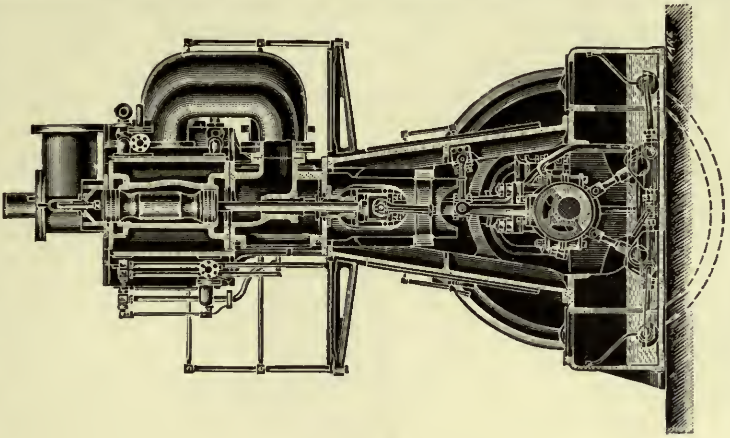


Fig. 9.—Transverse Section.

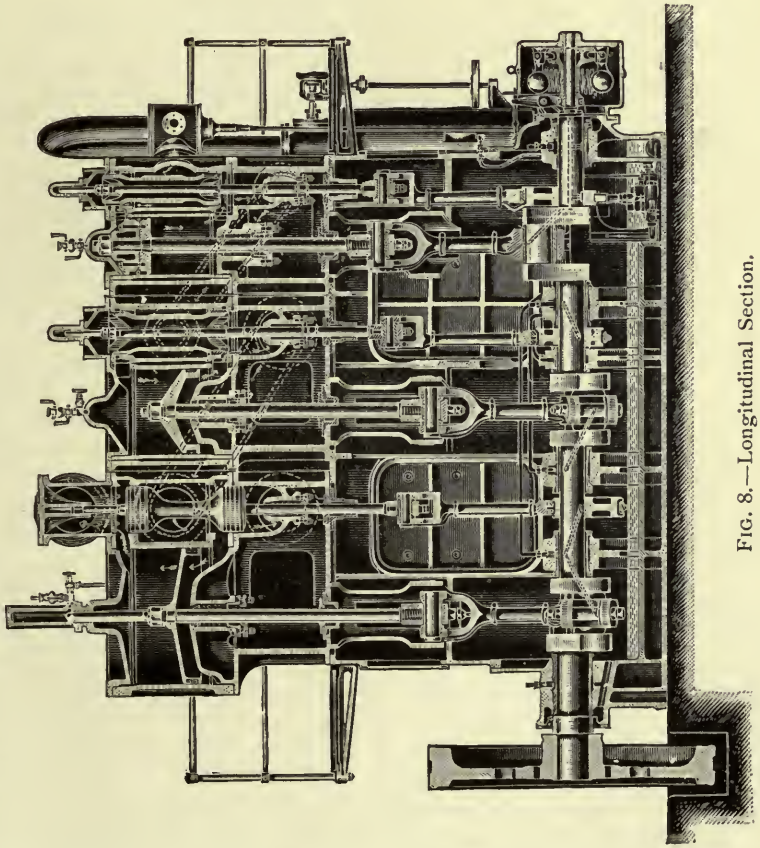


Fig. 8.—Longitudinal Section.

Belliss & Morcom Triple-Expansion High-Speed Engine.

The term quick-revolution is used in preference to high-speed, as on account of the short stroke of piston the advantages resulting from high speed of revolution are obtained without the severe strains on the working parts, resulting from excessive speeds of piston, and which have proved a frequent cause of breakdown in long-stroke engines, even when running at much lower speeds of revolution.

Great care has been taken in the design to secure all the requirements for sound and reliable manufacture, ready access for examination, lubricating and draining, and the numerous other requirements which long experience, with about 250,000 horse-power of electric light, power and traction machinery turned out, has shown to be so necessary to the efficiency and reliability of the engine.

Although it has been the fashion to supply separators to quick-revolution engines, these are not now fitted unless specially mentioned, as such appliances are of very doubtful utility, and useless with superheated steam.

The compound engine is seen in Figs. 6 and 7, in longitudinal and transverse sections, showing the general arrangement together with the central distributing piston valve. Figs. 8 and 9 show the triple-expansion engine in section.

The governor employed is of the throttle type, direct driven on the engine shaft; it is shown in Fig. 10 partly in section.

The high-speed type of engine also has great advantages with respect to governing. This results from the fact that, while in the same interval of time, say one minute, the slow-speed engine would have possibly 400 impulses, the high-speed engine, running at three times the speed of revolution, will be subject to 1800 impulses, or 4½ times as many, giving the governor a proportionately better control.

For the same reason the high-speed 3-crank double-acting engine gives twice as good governing as a 3-crank single-acting engine. This is shown by the governing performance of the engines at the Waterloo and City Electric Railway. Fig. 11 is a diagram showing the results of the works tests of these engines, as carried out under Professor Kennedy's supervision, plotted to scale. It will be noted that when the load was suddenly switched off the momentary variation from the mean speed did not exceed 2½ per cent., and the permanent variation 1 per cent. This excellent performance is fully maintained by the results under actual daily working conditions, as with the railway in full operation, with the load on the dynamos constantly varying from 50 to 350 ampères, or more, the speed indicators remain perfectly steady and almost immovable. Readings were taken of the tachometer and ammeter in connection with one of the sets every half-minute for ten minutes, with the result that the maximum momentary deviation from the mean speed, for any change of load, was found to be one-half of 1 per cent.

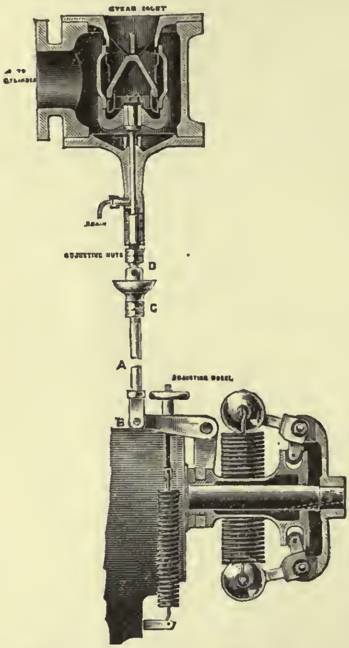


Fig. 10.—Sectional Elevation of Belliss & Morcom Governor.

There is one more point which should be taken into consideration, namely, the fact that the space between the casing and the cylinder stuffing boxes for the intermediate-pressure and low-pressure cylinders exceed the stroke of the engine. This somewhat adds to the cost of the engine, but effectually prevents the possibility of oil being carried up into the cylinders by the piston rods, with resulting damage to the boilers. On account of the fact that engines for traction work run most of the time at light load, with a vacuum in the low-pressure cylinder even on the up-stroke, this point is of special importance.

Plate I. shows the triple-expansion engine supplied to the Leeds Corporation.

This engine is designed to exert 2000 brake horse-power as a normal full load at a speed of 200 revolutions per minute, with a steam pressure of 170 lbs. per square inch condensing. It has also to exert an overload of 10 per cent., or 2200 brake horse-power for short periods of time, and on test a maximum load of 1887 kilowatts, say 2900 brake horse-power, was actually carried.

The engine has high, intermediate, and low-pressure cylinders working on three cranks at equal angles, the dimensions of the cylinders being 23-inch, 35-inch, and 55-inch diameter respectively, with a stroke of piston of 30 inches, giving 1000 feet per minute piston speed. The cylinders are fitted with piston valves throughout, this being in accordance with the firm's usual practice. It has been found by direct test that not only are piston valves best for smooth running and efficiency, but also for economical performance.

A special feature of the Belliss & Morcom engine is the forced lubrication of the motions.

In this system the oil is drawn clean and pure from a reservoir by means of a force pump without valves or packing, driven off an eccentric on the crank shaft. From this pump it is distributed evenly under pressure to every bearing in a continuous and regulated stream. The oil, after escaping from the bearings, falls into the receiving tank cast in the engine bed-plate, and thence passes through a strainer to the pump, and so on, for many months. The oil may at any period be taken from the reservoir, and after filtration be used again. To compare this method of lubrication with the splash type, or the usually insufficient and somewhat irregular ordinary type, appears unnecessary. Suffice it to say that these latter methods are usually employed with engines in which the presence of oil is not considered necessary to prevent knock. An important point in lubrication in which double-acting engines are superior to their single-acting rivals is, that in the principal bearings of the former there is a low-

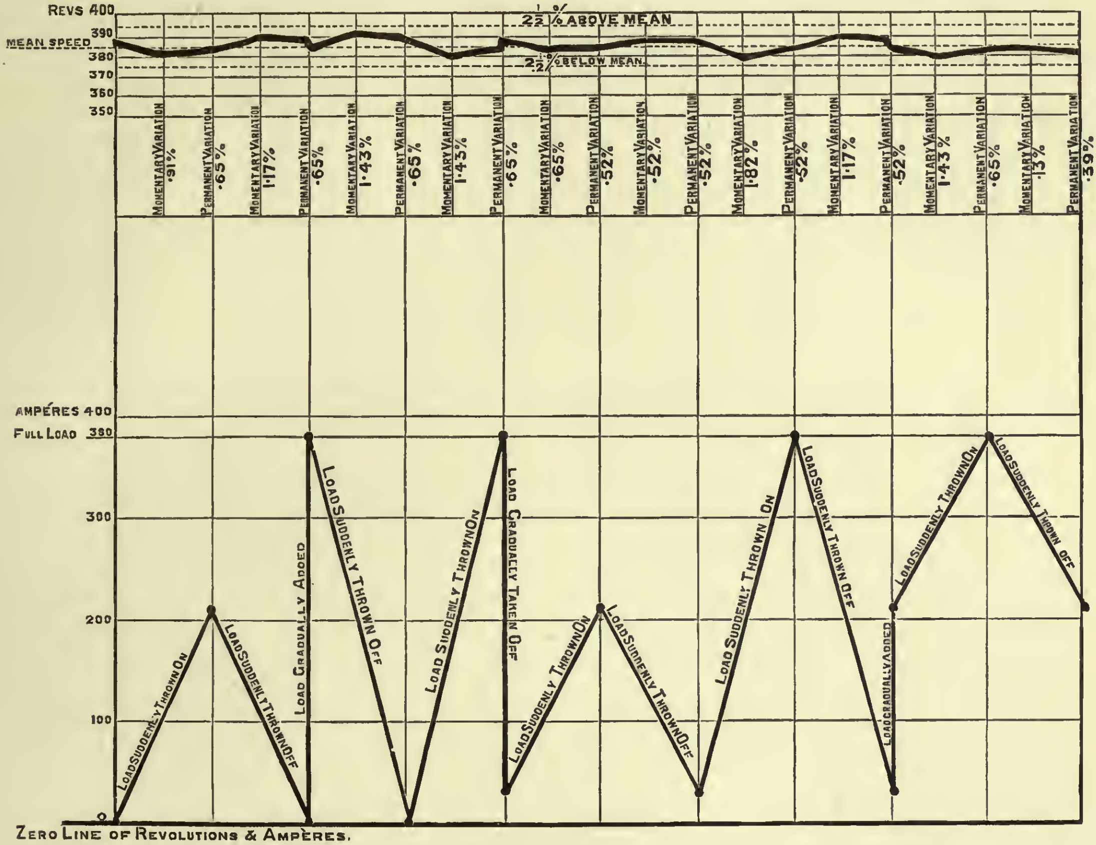


FIG. 11—Diagram showing Results of Switching on and off Various Loads of a Belliss Electric Traction Set.

pressure zone in the bearings constantly revolving round the pins and brasses, and the oil which keeps in this low-pressure space is constantly bathed round the entire surfaces of both bearings and pins, and as the stress at the varying points of maximum pressure is entirely removed once per revolution, and metallic contact thus almost entirely prevented, there can be but little metallic wear. With the bearings of single-acting engines which are in constant thrust this low-pressure space does not revolve, and there is consequently difficulty in getting the oil to the place where it is most needed, *i.e.* the place of greatest pressure, and so metallic contact often occurs.

THE REAVELL ENGINE

Expansion of steam in a compound engine is usually carried out by transferring the steam from a high-pressure cylinder to a larger low-pressure cylinder.

Expansion can, however, be obtained by transferring only a portion of the steam already expanded in the first cylinder, in which case the second cylinder may be of the same size as the first cylinder. The cycle will be clear from the diagram, Fig. 12.

Referring to Fig. 12, steam is admitted to a cylinder at W, having a large clearance volume at the beginning of the stroke, this clearance having been filled by compression during the later part of the previous stroke with steam at boiler pressure. Cut-off takes place at X, or other point determined by the automatic governor; the steam then expands to Y.

As the piston is on the dead centre, communication is opened between the top and bottom of the cylinder, which remains open to point Z, transferring steam to expand in the bottom of cylinder to atmospheric line. The steam in the upper side is compressed from Z to W, and the cycle repeated.

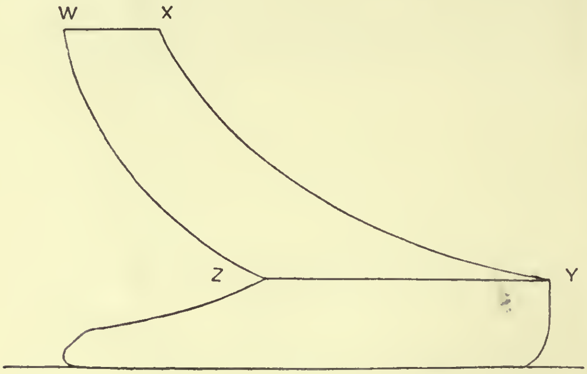


FIG. 12.—Theoretical Diagram.

Referring to the sectional illustrations (Figs. 13 and 14), it will be seen that the steam inlet flange is on the body of the cylinder itself, there being a steam jacket of considerable size between the working barrel and the outside of the cylinder, and between the inner and outer cover.

The valves of the engine reciprocate in a central valve liner secured in the bottom of the cylinder as shown, and the piston reciprocates in the annular space between this liner and the cylinder walls. The steam, entering through the stop valve, passes up between the inner and outer cylinder walls and covers, and is admitted into the valve liner through ports A near the top.

From the inside of the liner the steam passes into the cylinder through spiral ports C up to the point of cut-off, the clearance space shown above the piston being already filled with steam up to initial pressure, as before stated, and the cut-off being effected by the valve D driven by the slide rod.

After an early cut-off, the precise point of which is controlled directly by the governor, the steam expands during the remainder of the down-stroke, and while the crank is turning the bottom centre the ports E in the centre of the liner about half-way in the stroke of the engine are opened by the valve F, called the transfer and exhaust valve.

This valve F at the same time opens the ports G at the bottom of the cylinder, so that while the piston is making its up-stroke a communication is made between the top and bottom of the cylinder, transferring steam at equal pressure and temperature from the top to the bottom of the piston. This transfer continues for about half the stroke. In other words, about one-half of the steam which was above the piston is transferred to the other side.

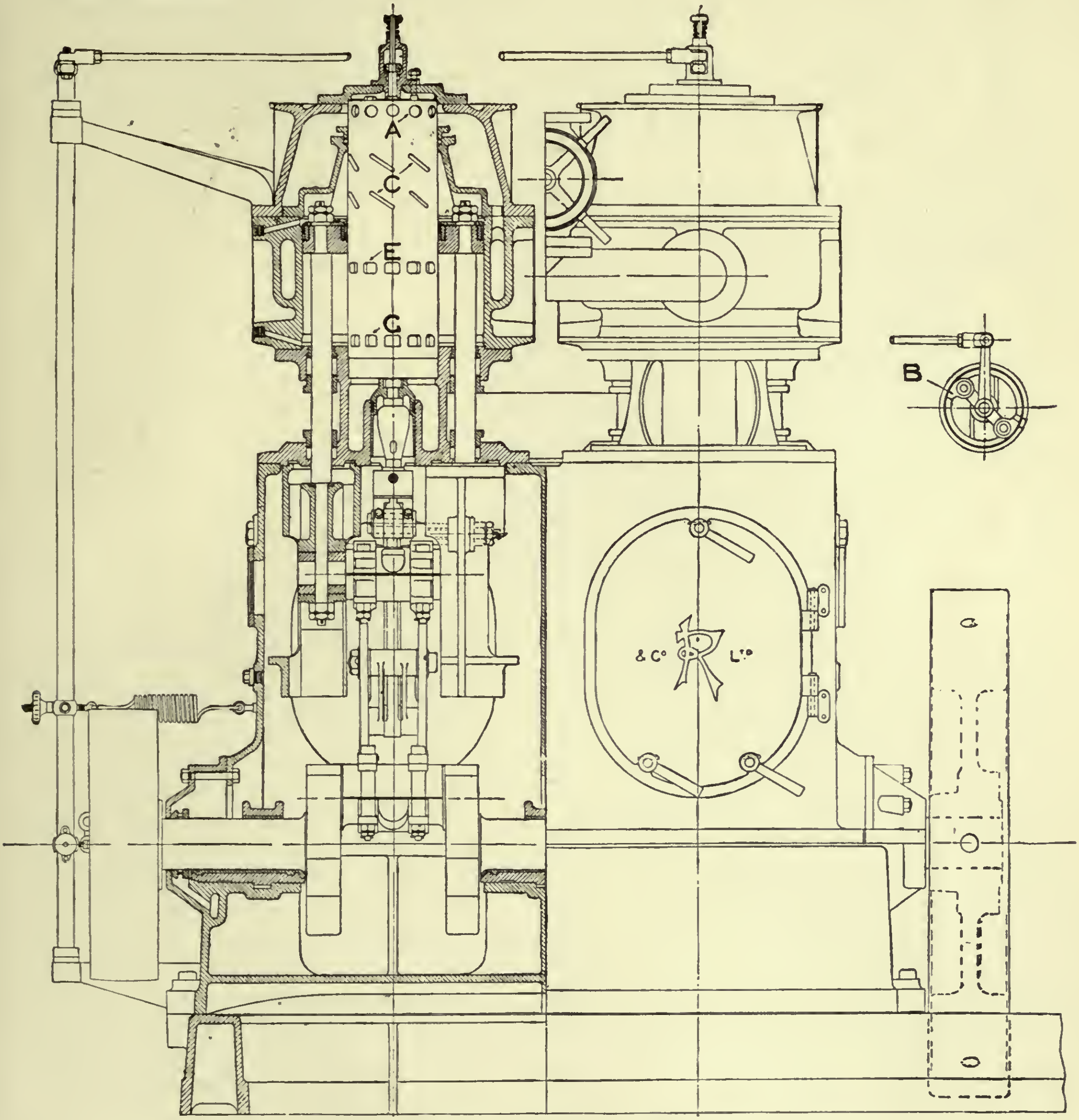


FIG. 13.—Sectional Elevation of Reavell Engine.

The transfer is closed first by the piston overrunning the ports E in its upward stroke, and immediately afterwards, by the valve F closing the ports E and G.

The steam transferred to the under side then completes its second stage of expansion, and at the end of the upward stroke the exhaust valve opens and allows this steam to escape to the atmosphere or the condenser.

In the meantime the steam which remained in the cylinder above the piston when the transfer closed is compressed during the latter half of the upward stroke, and the clearance space in the cylinder is so proportioned that this steam shall be compressed to initial pressure when the termination of the stroke is reached, and the valve D opens for the next admission of steam. By this means the reciprocating parts are brought to rest, and the inertia is taken up by means of the working fluid itself, while at the same time the parts which will be first touched by the entering steam are already heated up to initial temperature, and thus cylinder condensation is reduced.

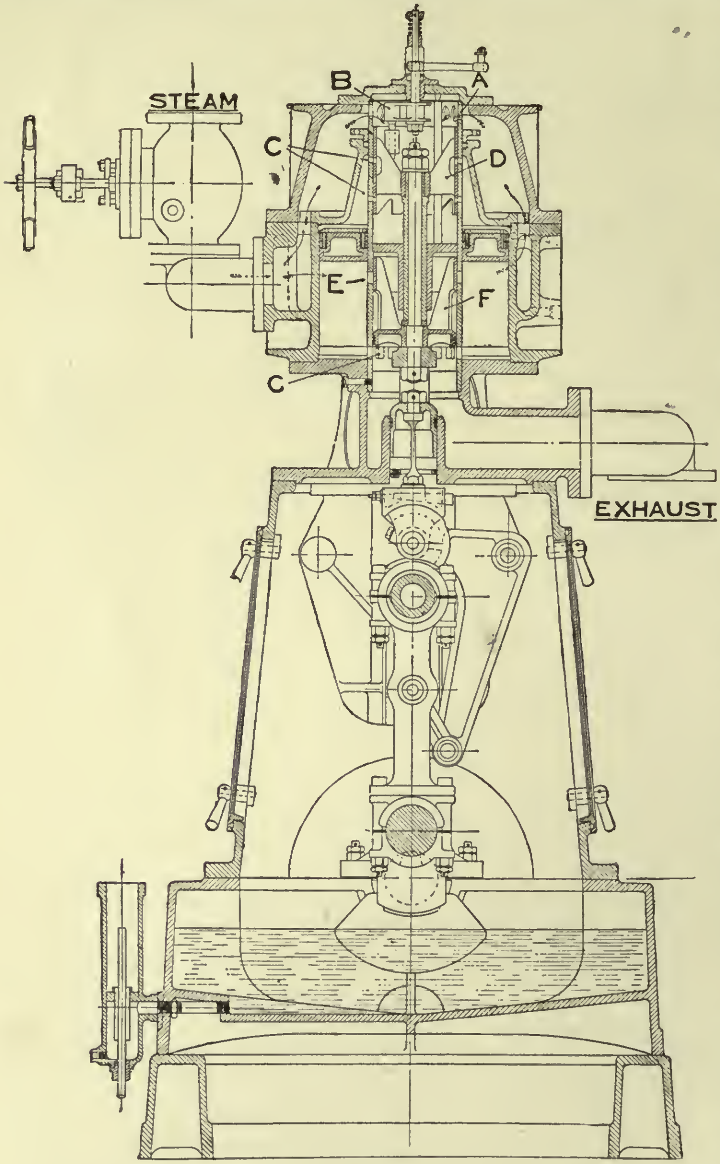


Fig. 14.—Transverse Section of Reavell Engine.

Very accurate and regular governing of the speed of the engine is obtained by a crank shaft governor, which acts through the levers and governor bridge B and varies the point of cut-off of the admission valve D.

This governor bridge B has two guide studs fixed to it, which pass through holes in the admission valve D.

The valve D, though reciprocated by the slide rod, and having a constant stroke, is free to be rotated by the guide studs on the bridge B, and the ports in this admission valve D are so arranged in connection with the ports in the valve liner itself that a slight axial movement will cause an alteration in the point of cut-off.

The valves are driven by a radial form of valve gear operating from a point in the connecting rod, and the positions of the valve gear centres are so chosen as to enable a considerable variation in the point of cut-off to be obtained, with an exceedingly slight change in the amount of lead.

An oil and water bath is formed in the bottom of the crank chamber, into which the bottom end of the connecting rod dips at every revolution, throwing a constant stream of lubrication over the working surfaces.

All the bearings have exceptionally large surfaces, so that they are subjected to low pressure per unit of area, and can be run for long periods without attention.

The perspective view shows a complete electric generating set as supplied to various electric generating stations.

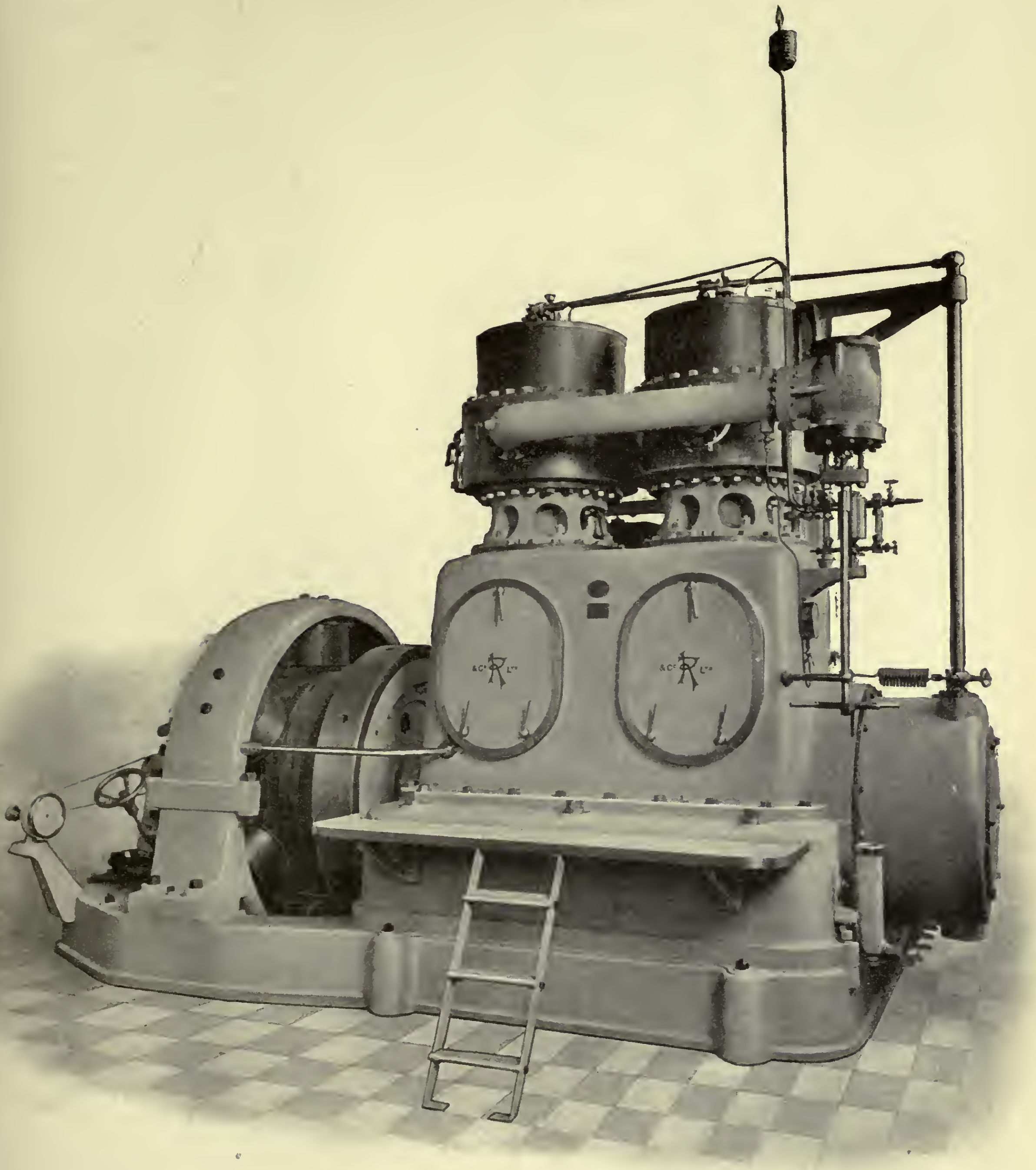


FIG. 15.—Reavell High-Speed Engine.

THE SENTINEL HIGH-SPEED ENGINE

This engine, shown in Figs. 16 and 17, is in general design what has now come to be regarded as the most suitable type for a highly economical high-speed engine for electric lighting and power purposes principally, but also suitable for almost any class of work where high economy, steady running, good governing are required; while the first cost as well as the cost of upkeep are very low. It is arranged with three cylinders and three cranks, each cylinder having a separate valve of the balanced piston type, and driven off a single eccentric with the fewest possible number of working parts, all as shown in section (Fig. 17).

The action and distribution of the steam is similar to the usual 3-crank triple-expansion marine engine. Each valve takes its admission steam at the centre and exhausting over the ends, so that the highest pressure and temperature steam is kept to the inside, and the glands are exposed to only exhaust steam. The cylinders are not jacketed, as it has been found by exhaustive tests of similar engines that the high speed of rotation has such an effect in reducing the initial condensation by shortening the time during which the steam is present in the cylinder that no real advantage is derived from jacketing, at any rate sufficient to justify the extra cost of fitting them.

Pistons and reciprocating parts are all made of equal weight, and the cranks, being at 120 degrees apart, the balancing of the engine is almost perfect. The inertia of the reciprocating parts is taken up during the exhaust stroke by a judicious amount of cushioning, which, by filling the clearance space before admitting live steam, is also conducive to economy.

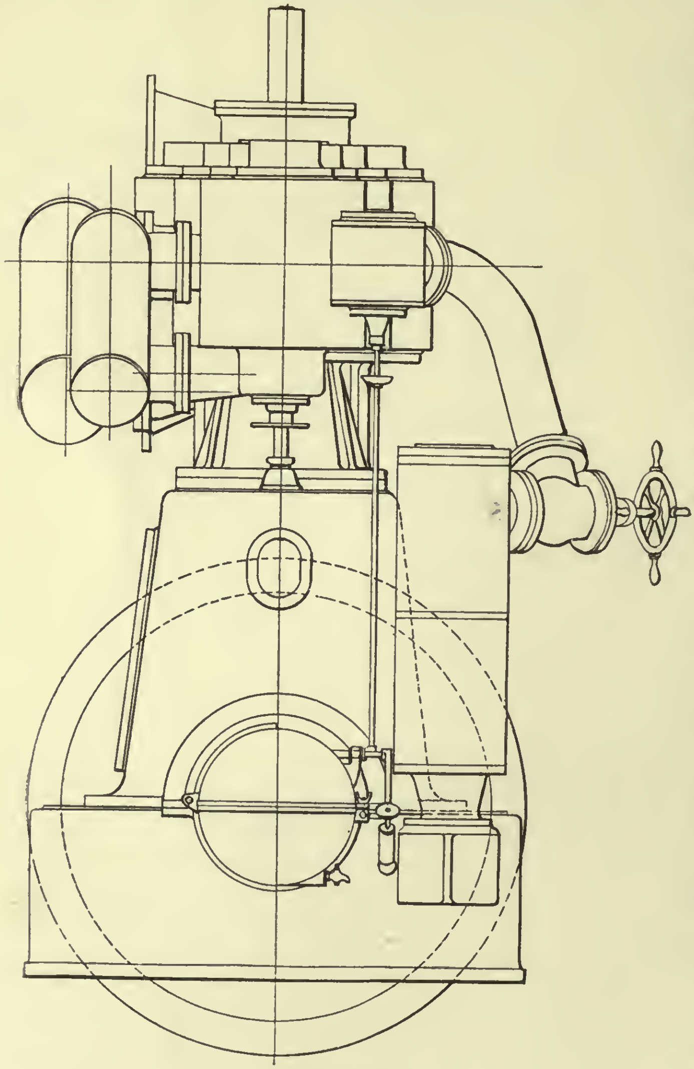
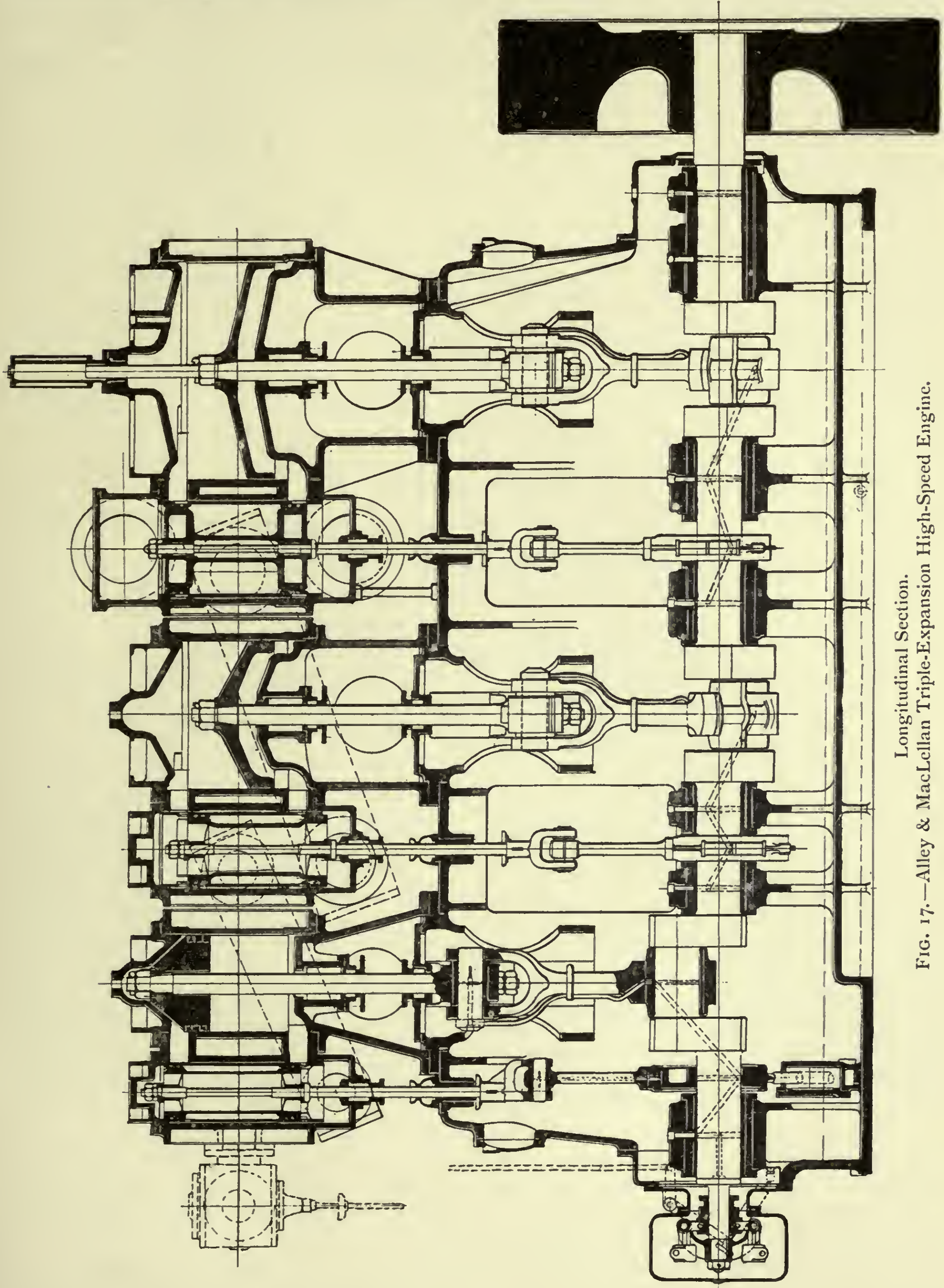

End View.

FIG. 16.—Alley & MacLellan Triple-Expansion High-Speed Engine.

The cylinders are lubricated in the usual way by a sight feed lubricator. All other working parts are very sufficiently lubricated by one (or two in the larger sizes) valveless oil pump driven off the high-pressure eccentric, and delivering oil under a pressure of 10 to 15 lbs. per square inch to all the bearings. Means are provided for regulating this pressure while the engine is running.



Longitudinal Section.

FIG. 17.—Alley & MacLellan Triple-Expansion High-Speed Engine.

The engine is fitted with a powerful centrifugal governor built on an extension of the crank shaft, and having positive control of a balanced double-beat valve on the high-pressure cylinder. The governor is provided with a regulating spring, so that the speed may be varied while running to an extent of about 5 per cent. up or down.

For taking overloads up to about 25 per cent. the engine may be fitted with a hand operated bypass admitting high-pressure steam to the high-pressure cylinder, or else this may be obtained automatically by an auxiliary bypass valve controlled by the governor, which opens this valve on the speed falling below the normal due to an overload coming on.

In order to facilitate rapid warming up of the engine when started each day it is fitted with a patented arrangement consisting of a bypass on each cylinder, which admits hot steam direct to each cylinder instead of having to pass right through the engine before getting to the low-pressure cylinder, in which case most, if not all, of it is condensed before it gets there, and so takes a long time to heat up that cylinder. These bypass valves also allow perfect automatic drainage to take place in each cylinder, so that there is no accumulation of water, and thereby considerably reducing the danger of damage due to water hammering. This warming up is effected without requiring to turn the engine by hand at all, as is usually necessary, and is all done with the engine in one position. After standing a few minutes so it can be run up to speed and the load put on.

These engines are suitable for working with superheated steam up to about 650° Fahr. without any alteration, but for higher temperatures special precautions would be adopted.

The cylinders are of the best re-melted close-grained, Scotch cast iron, free from blow-holes, thoroughly cleaned and accurately machined. They are all fitted with liners in the valve chest, and the ports are milled out to accurate dimensions. They are lagged with non-conducting material and cleaded with blue steel held in place by bright steel bands.

The high-pressure and mean-pressure pistons are of cast iron, and equal in weight to the low-pressure piston for balancing purposes. The low-pressure piston is of the best quality of malleable cast iron. They are coned so as to secure ample strength as well as good drainage, and machined all over and fitted with cast-iron Ramsbottom rings for the smaller sizes and special rings in the larger. They are securely fixed to the piston rod, and have no junk rings, studs, or loose parts which could possibly work loose and cause trouble.

The valves are all of the balanced piston type, and of best quality cast iron. The rings are of a special form, combining the best qualities of both the solid and spring types, so that whatever little wear which may take place after long period will not produce considerable leakage, as occurs with solid rings. The valves work in cast-iron liners, having the ports milled out and provided with bars to prevent the rings catching in the ports.

The piston rods are forged in one piece with the cross-head so as to make the most secure job possible, and are carefully machined all over, the rods themselves being ground. The cross-heads are fitted with removable cast-iron slides working in circular guides. The cross-head pins are of special steel, hardened and then ground. The cross-head is fitted with adjustable brasses secured by mild steel cap.

The connecting rods are forged from the best mild steel, of the usual "Marine" pattern, with a fork at the top end in which is fixed the cross-head pin. The bottom end is made with a foot to take the crank pin "brasses," which are made of malleable cast iron lined with tin basis white metal and adjustable. The bolts at both ends are made of best Admiralty steel, and have case-hardened nuts.

The crank shafts are of the 3-throw type, made in one piece from the best mild steel, the cranks being cut out and the whole carefully machined all over, balanced for high-speed running. The journals are of ample length to distribute the load well and keep down wear.

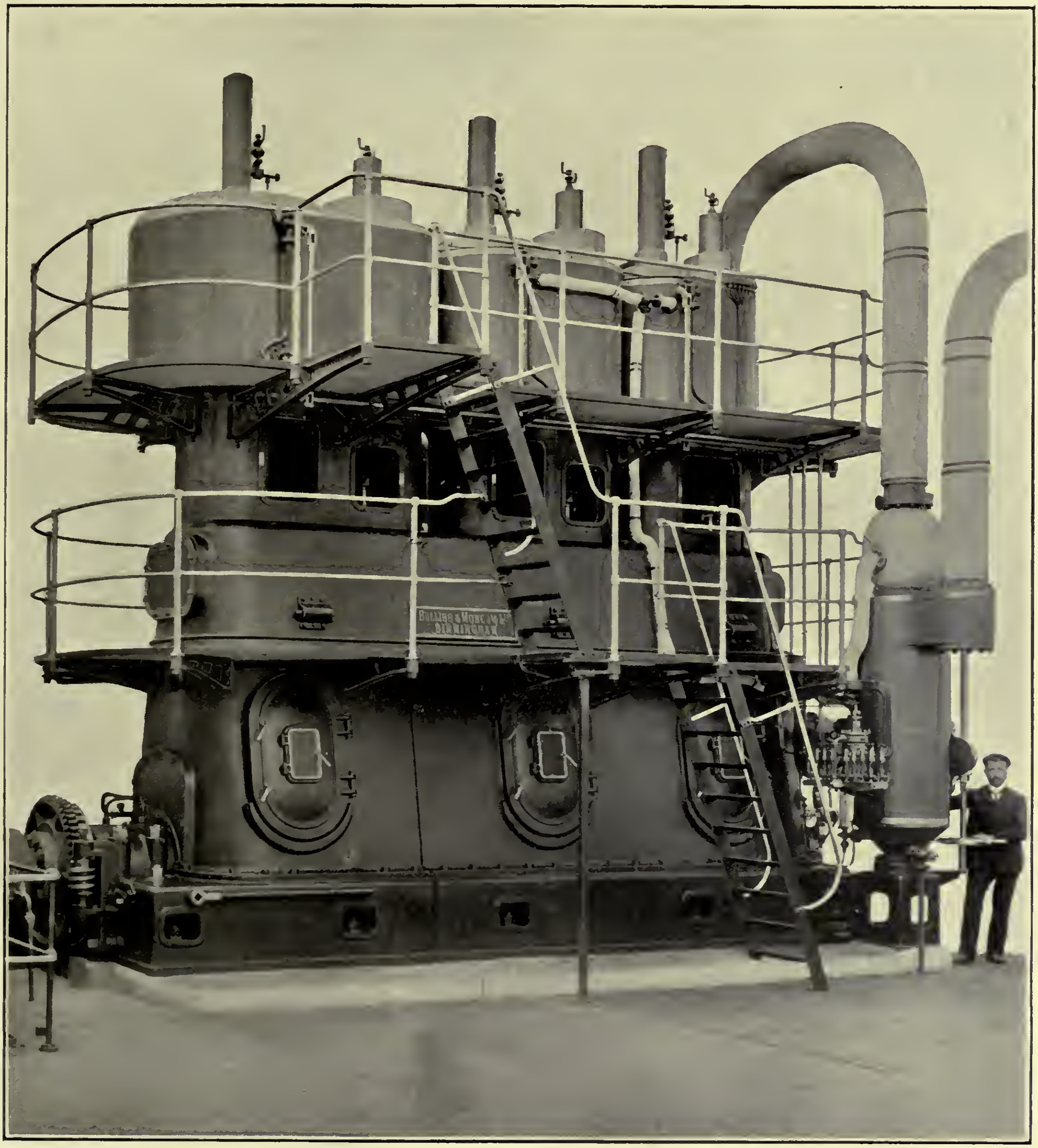


Plate I.—Triple-Expansion Double-Acting High-Speed Engine.

The eccentric straps are of best malleable cast iron, lined with white metal and adjustable.

The pulleys are of cast iron, securely fixed to the crank shaft by two bolts and cotters.

The main bearings are of cast iron, lined with white metal, hammered in, accurately bored in line, and the shaft is bedded in most carefully.

Usually the packings are of the floating metallic type all through for rods over 1½ inch diameter.

The governor is of the throttle type built on an extension of the crank shaft, and having positive control of a balanced double-beat valve. It is also adjustable while running. The usual requirements for governing for the most fluctuating loads can be complied with.

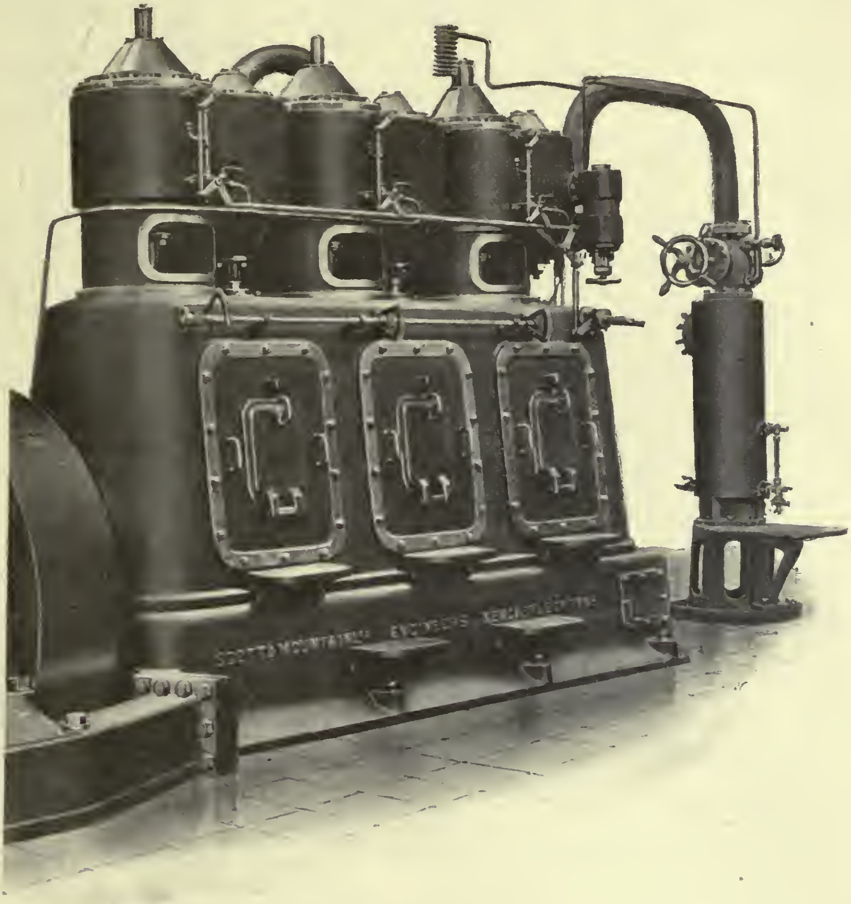


FIG. 18.—Scott & Mountain 3-Cylinder High-Speed Engine.

Lubrication is effected by valveless oil pumps supplying oil under pressure of 10 to 15 lbs. to all the bearings.

Plate II. shows the engine complete.

SCOTT & MOUNTAIN'S HIGH-SPEED ENGINES

This engine has been largely used in electric lighting installations. Its feature is the use of two low-pressure cylinders and one high-pressure cylinder on three cranks at

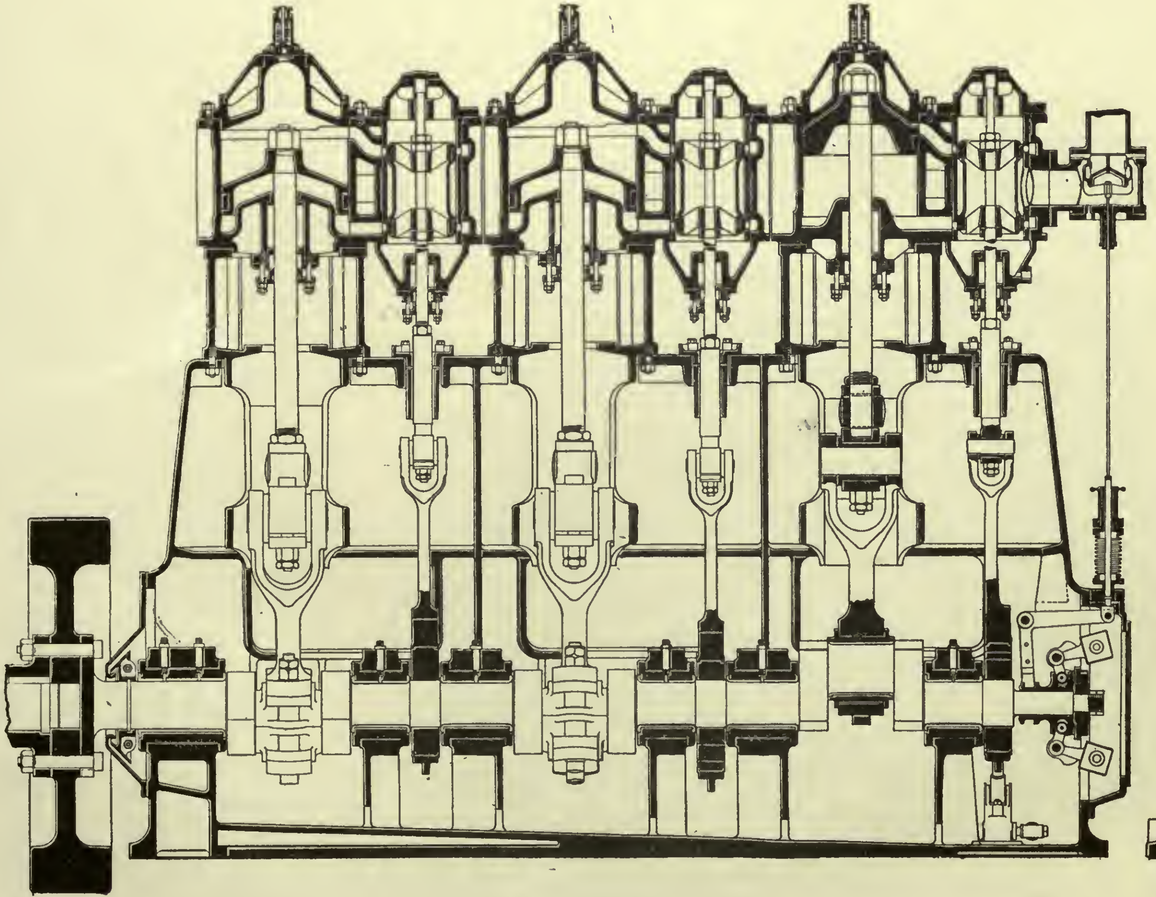


FIG. 19.—Longitudinal Section.

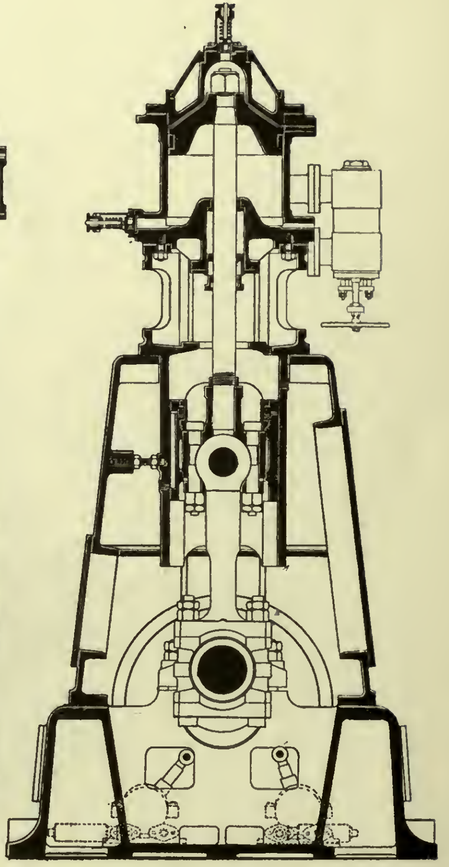


FIG. 20.—Transverse Section.

Scott & Mountain 3-Cylinder High-Speed Engine.

120 degrees apart. This gives good balancing and economy of steam. The valves are all piston valves, and the governing by throttle.

The engines are all fitted with the latest system of forced lubrication, which consists of a valveless oil pump delivering oil under pressure to all working parts. The crank shafts are of large diameter, with specially large bearing surfaces.

The longitudinal and transverse sectional views (Figs. 19 and 20) show the whole design of the parts, and the complete view (Fig. 18) the external appearance of these engines. The design offers great accessibility to the piston valves and packing glands.

SINGLE-ACTING HIGH-SPEED ENGINES

In this class the Willans' engine has already been referred to. There remain for consideration several others of this class now to be described.

THE CAREL'S ENGINE

This engine is much the same as the Willans', in adopting air cushioning in a cylinder which forms the guide for the cross-head. It differs, however, very much in the valve arrangement. It has rotary valves, and these form the leading features of the engines.

The engines are single acting, and are built with two, three, four, and six cylinders or more, placed in couples and superposed in tandem. They are also built as high-pressure engines or for double and triple-expansion, and with two, three, or four cranks. The bed-plate can, as said before, be fitted for coupling dynamos, pumps, ventilators, etc. The driving shaft works constantly in the oil bath previously mentioned, and lubricating at the same time the bearings of the cross-heads and of the connecting rods. The valves are rotary, symmetrically built, and driven from the crank shaft by bevel gears. The use of cams or eccentrics employed in all other systems of high-speed engines known at the present day is entirely done away with. This is all clearly shown in the sectional view (Fig. 21).

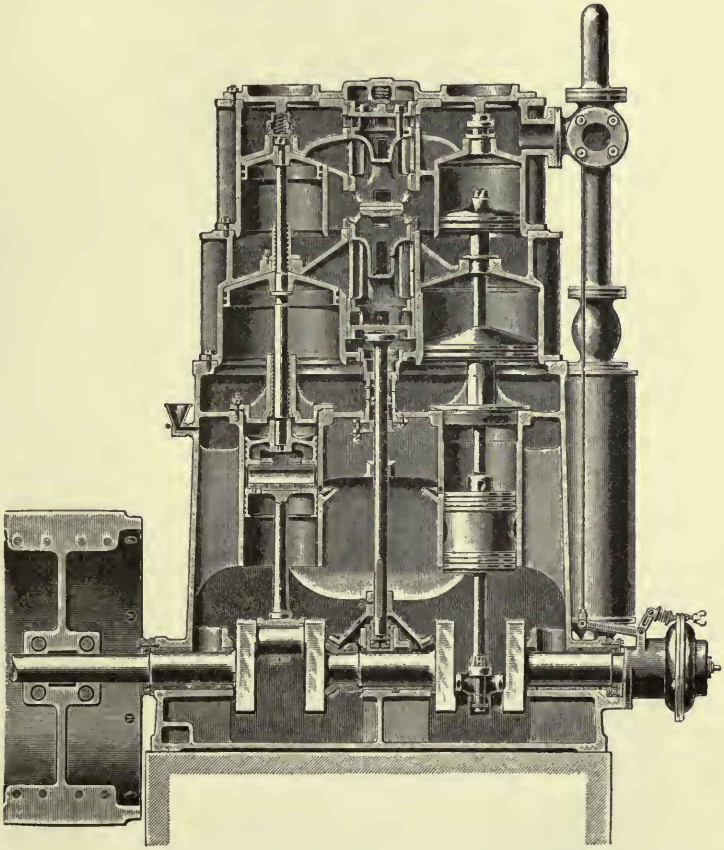
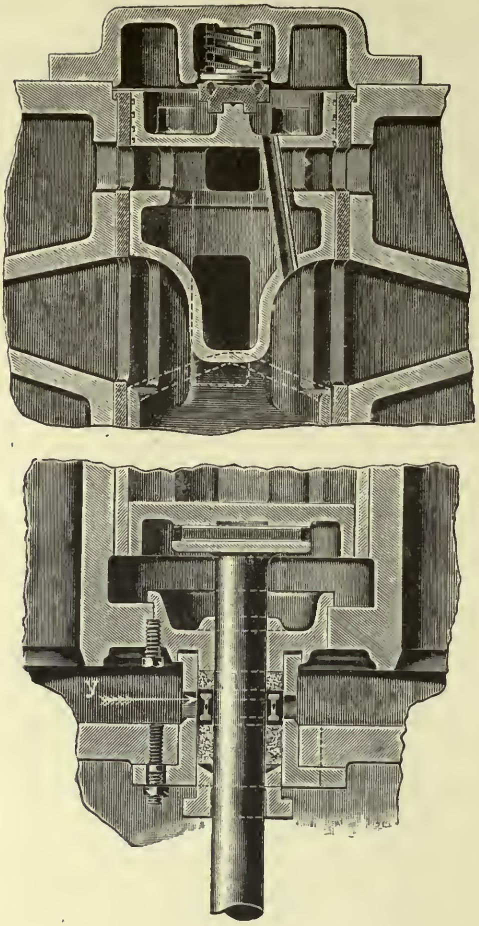


Fig. 21.—Carel's Engine. Longitudinal Section.

The top part of Fig. 22 shows the construction of the rotary valves. Rotary



valves are quite a novelty in high-speed engines, and offer considerable advantages if they can be kept steam-tight. This is difficult to do; but the construction here shown appears to overcome that defect in rotary valves. The design, together with first-class workmanship, is admirably suited for the work.

The rotary valves, made of hard cast iron, rotate in phosphor-bronze sleeves. They are balanced in all directions, and there is consequently no wear. The valve rod turns in a special stuffing box, in which is placed a ring with a channel which leads the condensed water of the receiver into the discharge pipe of the cylinders, thus avoiding the introduction of this water into the oil tank and a consequent alteration of the composition of the oil bath.

The two ends of the valves, and also the valve rod, are carried on ball bearings.

The cushioning piston and connecting rod cross-head are shown in the sectional view (Fig. 23), and

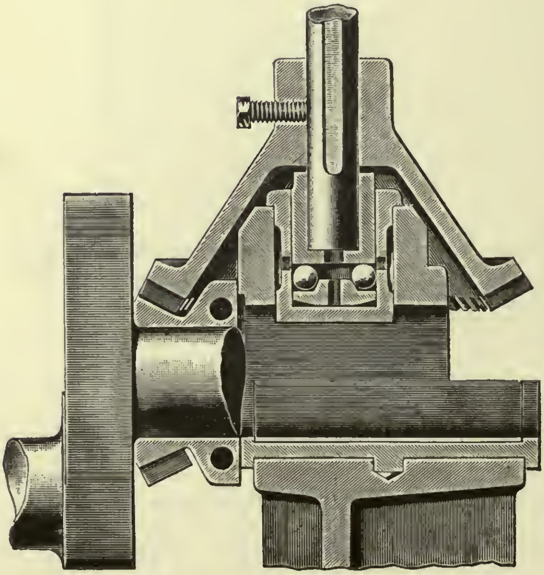


FIG. 22.—Rotary Valve driven by Bevel Gearing.

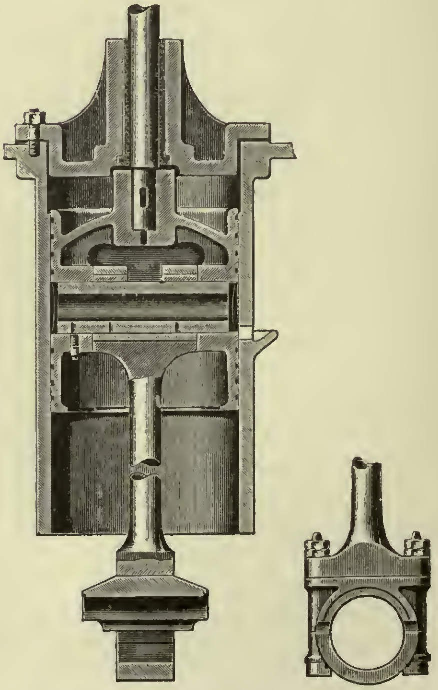


FIG. 23.—Guide Piston and Cushioning Cylinder.

Carel's Engine.

in Fig. 22 the two valve-driving bevel wheels, one of bronze the other of cast iron. The vertical rotary valve spindle is supported on a ball-bearing footstep as shown.

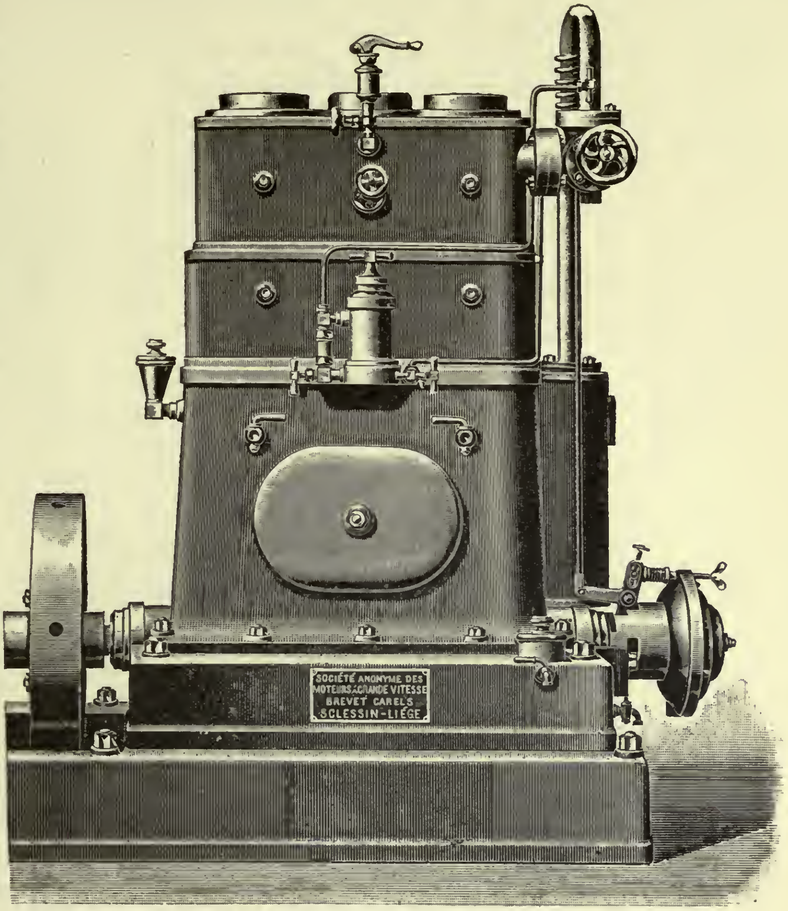


Fig. 24.—Carel's Engine.

Fig. 24 shows the external appearance of this type of engine. It is an engine worth considering closely as a type of high-speed prime mover.

The frame, which encloses all the moving parts of the engine, forms with the base an oil-tight tank containing the lubricating bath composed of pure water and castor oil.

By the rotation of the crank shaft the lubricant is projected in all directions inside the frame, and lubricates all the moving parts. Two doors in the frame allow an easy inspection of the engine.

The base has a double bottom, in which a circulation of cold water can be established in order to cool the oil bath when the engine is required to run day and night without stopping.

THE WESTINGHOUSE STANDARD ENGINE

The field of application of the Westinghouse standard engine is that in which the use of a simple non-condensing engine is consistent with commercial economy.

Economy of fuel and commercial economy are not always synonymous terms. There are many situations in which for various reasons the mere steam consumption of an engine is a matter of secondary consideration, and consequently there exists, and probably always will exist, a legitimate and active demand for a non-compound, non-condensing engine.

In some of the textile industries the requirements of the washing and dyeing processes use up all the exhaust steam from the engines, and often make drafts on the boiler for live steam in addition. Similarly, in paper mills the cooking of the stock and the drying of the finished product enable a profitable disposition to be made of the exhaust from simple engines. In sulphite fibre mills the high-pressure steam used in the digesters is so many times the amount needed for power purposes that the exhaust from the engines will barely suffice to heat the feed-water for the enormous boiler plants required.

Where all the exhaust from an engine can be profitably used it is mistaken economy to try to make that exhaust less, as the deficiency must be made up by practically the same amount of live steam drawn directly from the boilers.

Clearance, generally regarded as the greatest bugbear of the designer, can, as the results submitted show, if properly used in connection with the variable compression obtained by the single valve steam distribution, be made a valuable factor of economy on engines which have to work under variable loads. On light loads the compression begins early and stops re-evaporation from cylinder walls, which is the greatest source of waste in the steam engine.

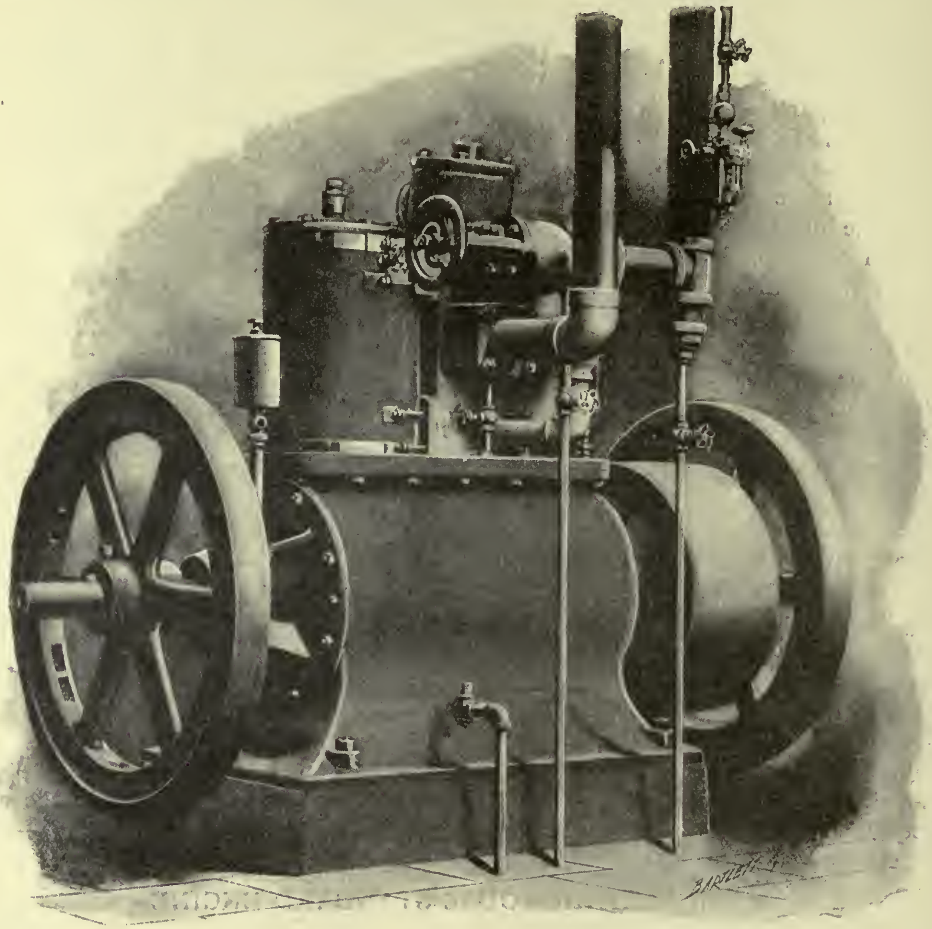


Fig. 25.—Standard Engine. Rear View.

In the 4-valve engine, with close clearance, the exhaust valves must always remain open until nearly the end of the return stroke of the piston, the point of compression remaining a fixture. This allows a maximum amount of time for the above-mentioned useless transfer of heat, and practically makes the amount of this loss constant, irrespective of the load on the engine, instead of reducing it with decrease of load, as can be done with the single valve steam distribution.

Engineers have almost without exception failed to appreciate the possibilities of the single valve steam distribution, regarding it as a sacrifice of efficiency to mechanical simplicity. Designers of single valve engines have directed their energies toward producing an engine which would give an indicator card approximating so far as possible what is recognised as the typical diagram from a 4-valve engine. Clearances have been cut down, necessitating later compression, which entails earlier release of

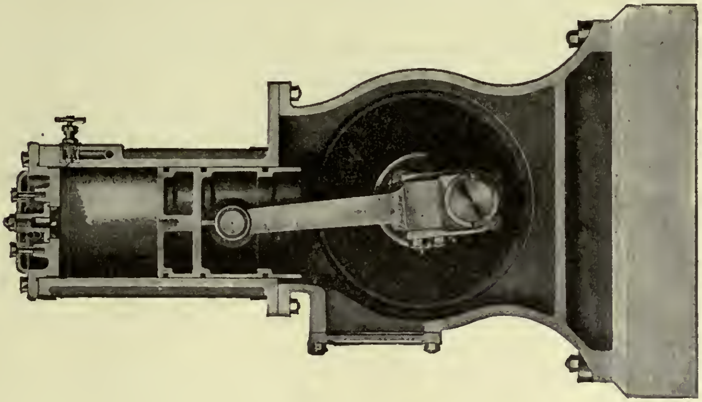


Fig. 27.—Cross Section.

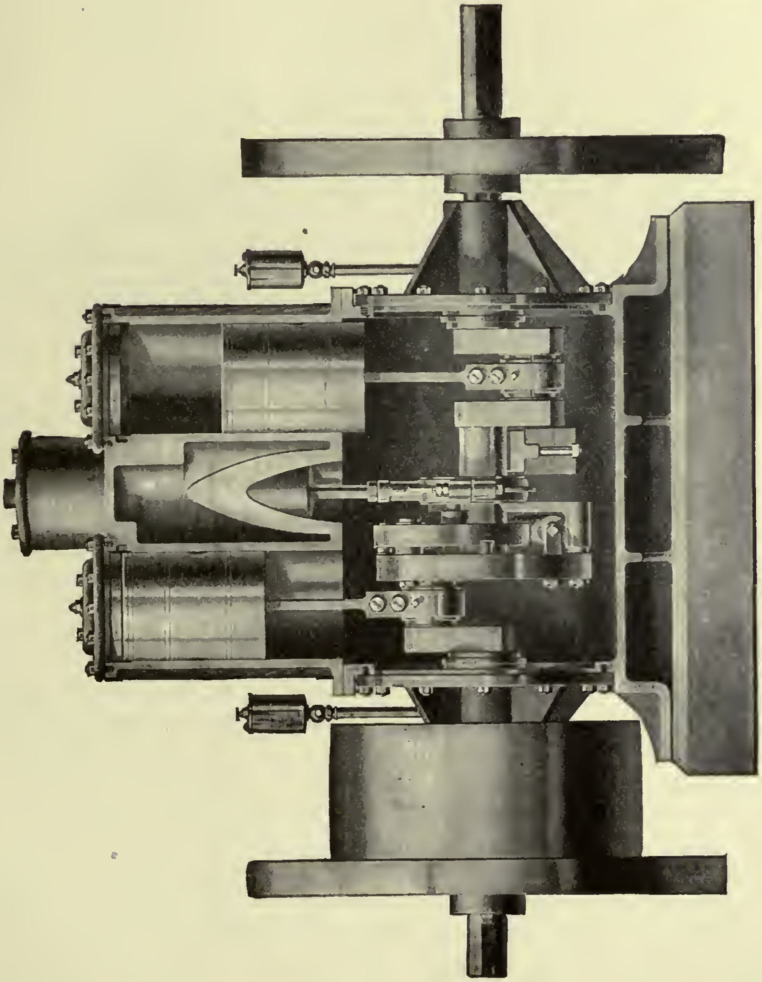


Fig. 26.—Longitudinal Section.

Standard Engine.

the expanding steam, giving in general a resultant steam distribution which has the faults of both the single valve and 4-valve systems and the virtues of neither.

Fig. 25 shows the Standard engine as seen from the rear, and Figs. 26 and 27 show the engine in longitudinal and cross sections.

Referring to the cross section through the cylinder (Fig. 27), it will be seen that we have a piston to which one end of a connecting rod is pivoted, the other end engaging with a crank. There is no piston rod, cross-head, stuffing box, or guide. This combination is admittedly the simplest mechanism that could be produced for the transformation of pressure on the piston into rotary motion at the shaft. That we have two such elements in each engine, so that one piston may be doing work while the other is returning on its idle stroke, is no added complication. A plain piston valve controls a single port to each cylinder for the admission, cut-off, and exhaust, actuated by a simple form of shaft governor.

The base or frame of the engine is a hollow casting called the crank case. On the top of the crank case are bolted the cylinders and steam chest, which are all cast in one piece. On the ends of the crank case are the crank case heads, carrying removable cast-iron babbitt-lined shells, which constitute the main bearings. The removal of either crank case head uncovers an opening in the end of the crank case of such size as to allow the shaft and governor to be easily taken out. Between the cranks is the centre bearing, which gives additional support to the shaft against the downward pressures imposed by the pistons and connecting rods. In the front of the crank case, kept closed by a suitable cover while the engine is running, is a large opening, through which all internal parts may be inspected and ready access had to every bolt or nut requiring adjustment.

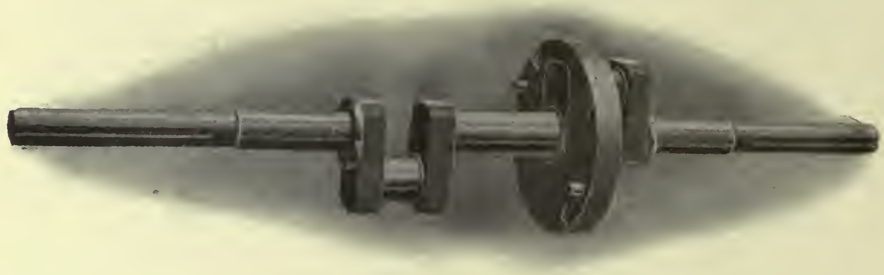


Fig. 28.—Crank Shaft.

The crank case is filled with water high enough to half submerge the crank pin when at the bottom of its throw, and on top of the water is floated a few gallons of heavy lubricating oil, of a quality especially made for this service. This is heavy-bodied oil of high fire test, and is commercially known as Westinghouse crank-case oil.

The motion of the cranks throws this mixture of oil and water freely over all the enclosed working parts, affording lubrication of the most ample and certain character. A wide experience has shown conclusively that the mixture of oil and water is a more satisfactory lubricant than oil alone. The mixture is less tenacious than the pure oil, and consequently it is thrown about more freely; furthermore, the crank case is open to the atmosphere through a vent pipe, so that the slow evaporation of the water prevents the temperature of the lubricant ever rising above 212°. In the ordinary course of operation a little water works past the pistons, sufficient in quantity to make up the small loss by evaporation.

The crank shaft, shown in Fig. 28, is forged from open-hearth steel in one piece, without a weld. The cranks are forged solid and cut out roughly to shape under a slotting machine. The shaft is then rough-turned nearly to size, after which it is taken to the foundry and has cast upon one of the crank arms a disc which forms a frame for the automatic governor. This disc is secured by a patented method which makes it impossible for it ever to get loose or rattle. The shaft is then put in the lathe again, and finish-turned all over, disc included, at one setting. The keyways are then milled out, and the disc drilled and reamed to receive the several pins and lugs which carry the governor parts.

The eccentric strap, as shown in Fig. 29, is of cast iron, hinged at the back, and closed at the front by a single bolt. The removal of one or more thin liners from between the upper and lower halves on the front side compensates for wear. The rod fits into a taper hole in the strap, and is held rigidly in place by a key passing through both strap and rod. The hexagon nut threaded on the lower end of the rod is not for the purpose of making any adjustment as to length, its sole use being to back the rod out of the strap when the key is drawn and it is desired to break this connection. The upper end of the rod is fitted with a renewable babbitt bushing, and engages with a case-hardened wrist pin.

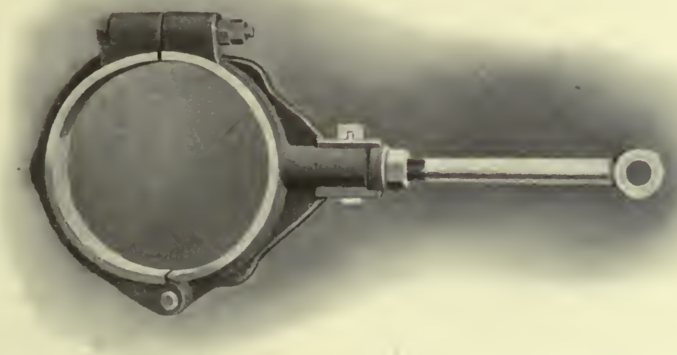


FIG. 29.—Eccentric Strap.

A line through the centre of either cylinder would not pass through the centre of the shaft, but through a point in front of the shaft at a distance equal to one-half the length of the crank. This construction reduces the angularity of the connecting rod one-half while the working or downward stroke of the piston is being made; on the upward stroke the angularity of the connecting rod is of course correspondingly greater, but as the pressures on the return stroke are trifling this increased angularity is of no consequence.

Figs. 30 and 31 are sectional views of cylinders, pistons, steam chest, and valve, on a scale sufficiently large to enable the construction and operation of the several parts to be readily understood.

In the left-hand section the steam chest has been shown as though it were exactly vertical, and directly in line with the two cylinders. In the actual engine a section through the centre of both cylinders would not show the steam chest, valve, and ports in section, but the slight distortion shows the relation of the parts more clearly.

The main valve V is of the piston type, packed with four spring rings, the tightest, most durable, and most perfectly balanced form of valve yet designed. Steam enters through the throttle valve at S, and passes into the annular space around the neck of the valve. In the section through both cylinders the left-hand piston is shown as just starting on its downward stroke, and the right-hand piston beginning its upward stroke. The valve has moved upward by the amount of its lap and lead, and is beginning to open communication between the steam space and the port A, admitting steam to the top of the piston, forcing it down. The extreme bottom edge of the valve has uncovered the lower port, establishing communication between the right-hand cylinder and the exhaust chamber E. The crank forces the right-hand piston up, the exhaust passing through the port B under the valve into E and out through the exhaust pipe.

As the revolution progresses the valve moves upward to the limit of its stroke, and starts downward, covering the port A again at a point determined by the governor, cutting off the steam supply and allowing expansion to take place in the left-hand cylinder. A little later the lower edge of the valve covers the port B so that the steam remaining in the right-hand cylinder is compressed. When the stroke is nearly completed the upper edge of the valve begins to uncover the port A, when release takes place in the left-hand cylinder. When the revolution is half completed the left-hand piston has reached the limit of its downward stroke and the right-hand piston is about to begin its downward stroke. The valve is then in the position shown in the right-hand section, *i.e.* travelling downward, beginning to uncover the port B admitting steam to the right-hand cylinder, and uncovering the port A leading from the left-hand cylinder. During the remainder of the revolution a cycle of operations occurs similar to that just described, except that these operations take place in opposite cylinders. The exhaust steam from the left-hand cylinder passes over the top edge of and down through the valve, which is hollow, into the exhaust chamber E.

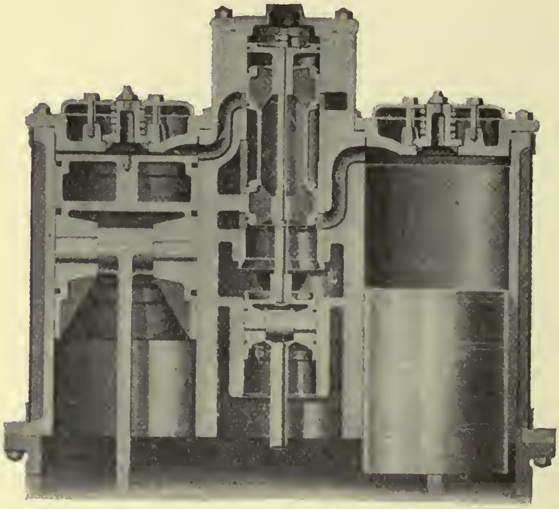


Fig. 30.—Longitudinal Section through Cylinders, Pistons, Steam Chest, and Valve.

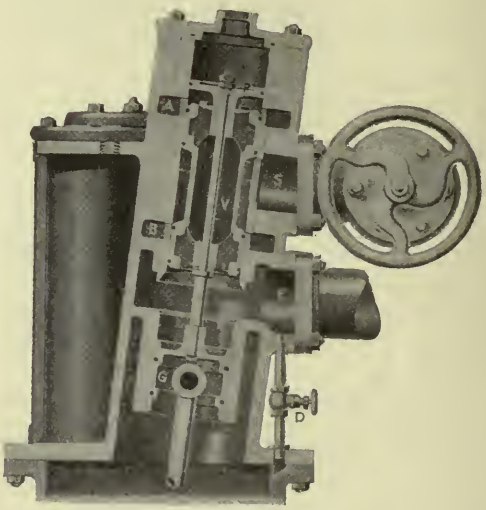


Fig. 31. —Transverse Section through Piston Valve.

The valve guide G is a small piston, of about the same diameter as the valve, which serves as a cross-head for the attachment of the eccentric rod, and at the same time prevents the exhaust steam from passing into the crank case. If the engine were exhausting against any considerable back pressure there would be an unbalanced downward force caused by the pressure of the exhaust over the area of the valve guide G. To provide against this the steam chest is extended upward, and a back pressure piston P attached to the valve stem, above the main valve, high enough so that it never comes down to the port A. The upper surface of P is open to the atmosphere through a hole in the steam chest cover, while the under side is subjected to the pressure of the exhaust, which exerts a force equal in intensity and opposite in direction to that due to the pressure on G, and consequently makes the balancing of the valve practically perfect.

D is a small drain valve connecting the exhaust chamber E with the crank case. It may be opened slightly if at any time the water supply in the crank case appears to be low, but under ordinary circumstances should be kept tightly closed while the engine is running.

The cylinder heads are polished, and fitted with spring relief valves to protect the engine from damage by reason of water coming over from the boilers or pockets in the steam piping. Two forms of relief valve are used: on the smaller sizes, up to and including the $8\frac{1}{2} \times 8$, it is a brass fitting which screws into the cylinder head. On the larger sizes it is made of iron, and is a part of the cylinder head. The springs are adjusted so as to just stop any shifting when the engine is carrying its load with full boiler pressure and a wide open throttle. When so adjusted these relief valves are highly efficient in taking care of sudden and unexpected charges of water.

For the arrangement of the cylinder drain valves, near the top of each cylinder is a boss, which is bored out to receive a brass bushing, which forms the body and seat of a small angle valve. A hole is drilled from the interior of the cylinder to the under side of the valve seat, and another passage is drilled from the upper side of the valve seat through a suitable rib or projection on the cylinder casting, to the exhaust chamber in the steam chest. The stuffing box, valve stem, and hand wheel only project through the cylinder jacket, all unsightly pipe connections being entirely absent. The cylinders are lagged with wood and covered with a sheet-steel jacket held in place by bands of polished brass at top and bottom.

The main bearing is a cylindrical cast-iron shell lined with the best grade of genuine babbitt metal, and fits into an accurately bored hole in the crank case head. This shell on the smaller sizes is in one piece, while on the larger sizes it is divided longitudinally into two pieces. It is held in place by two set screws. A polished brass oil cup of generous dimensions, with a graduated sight feed, delivers crank case oil at the centre, from which point it is distributed each direction by suitable grooves cut in the surface of the babbitt metal lining. Surrounding the shaft just outside the bearing shell, and inside the crank case head casting, is a small wiper ring, shown in section. This ring prevents the oil from working out to the end of the shaft, centrifugal force throwing it off into the chamber in the crank case head outside of and underneath the bearing shell, from whence it drains into the crank case, keeping up the supply so that it is rarely if ever necessary to add to it otherwise.

The engine being single acting, the lower half of the main bearing only is subjected to wear, and no adjustment is necessary to keep the shaft in contact. When the babbitt lining is worn down as far as it is safe to let it go the shell can be turned upside down, bringing the unworn half into service. In doing this it is, of course, necessary to see that proper oil holes and grooves are opened up on the opposite side, and that both bearings are reversed at the same time so as to preserve the alignment of the shaft.

The shaft governor of this engine, shown in Figs. 32 and 33, is of interest as an example of a type very largely in practical use.

A is the disc on the shaft mentioned previously in the description of the crank shaft (page 24), which serves as a support for the governor parts. BB are the two weights pivoted to the disc at *b* and *b*. C is the eccentric, made integral with the arm *c*, which is pivoted to the disc at *d*. DD are the springs, attaching at one end to the weights BB, and at the other by a lug bolt to the disc A. The long link *e* connects the two weights in such a way that they always move together. The short link *f* is attached at one end to the eccentric, and at the other to one of the weights, so that as the weights move out the eccentric moves across the shaft. Stop pins *ss* limit the outward travel of the weights.

The direction of rotation is opposite to that of the hands of a watch. The distance from *d* to the centre of the eccentric is greater than the distance from *d* to the centre of the shaft by an amount approximately equal to the lap of the valve. Consequently, as the eccentric is drawn toward the left across the shaft its centre approaches the centre of the shaft, decreasing the valve travel, and at the same time its angular advance is increased. The decreased travel, combined with increased angular advance, effects an earlier cut-off, without altering the point of admission. At shortest cut-off the valve travel is practically double the amount of the steam lap, and therefore no steam is admitted to the cylinders.

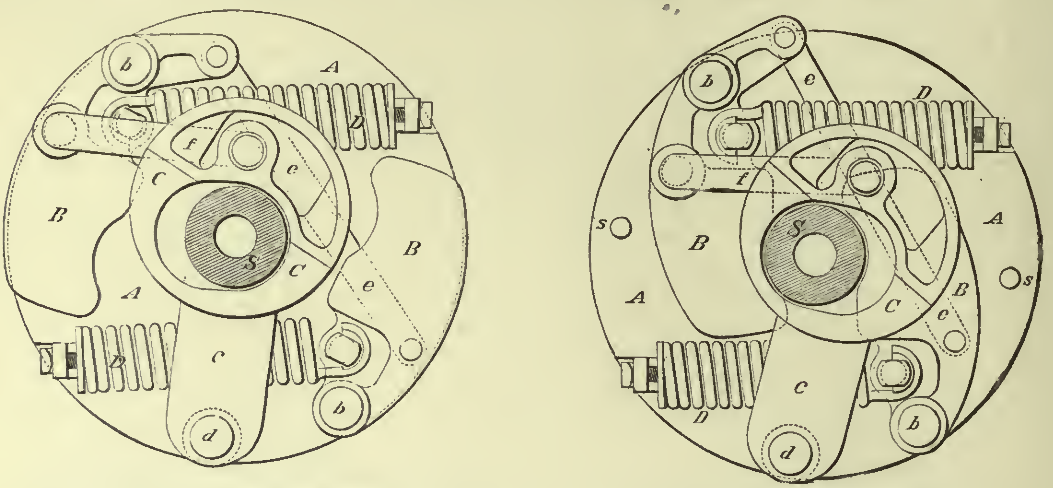


FIG. 32.—Earliest Cut-off. FIG. 33.—Latest Cut-off.

Governor of Standard Engine.

THE WESTINGHOUSE JUNIOR ENGINE

In this type of engine (Fig. 34) the valve is on top of the cylinders, and slides at right angles to the cylinder axis. The arrangement is clearly shown in section in Fig. 35, and in Fig. 36 in complete vertical section.

The steam chest forms a cover for both cylinders, incidentally effecting a saving of about forty shillings in the cost of a 35-horse-power engine. Spring relief valves in the front side of the steam chest, communicating with the ports leading to the cylinders, furnish protection against shocks from sudden charges of water coming over through the steam pipe.

The valve is of the piston type, packed with four spring rings, tight, and a reliable form of valve, and one which is perfectly balanced under all pressures.

Horizontal reciprocating motion is imparted to it from the up-and-down moving eccentric rod, through a bell crank rocker arm.

The eccentric rod is a section of hydraulic steel pipe, turned and polished. Screwed to either end, and secured with jam nuts, are babbitt-lined adjustable boxes, forming, with the spherical eccentric and the spherical end of the rocker arm, universal or ball and socket joints.

The action of the valve will be easily understood from the sectional view (Fig. 35). Steam entering at S fills the annular space surrounding the neck of the valve. When the parts are in the position shown the valve is moving toward the left, establishing communication between the steam space and the left-hand cylinder through the port A, the left-hand piston just starting on its downward stroke. The right-hand end of the

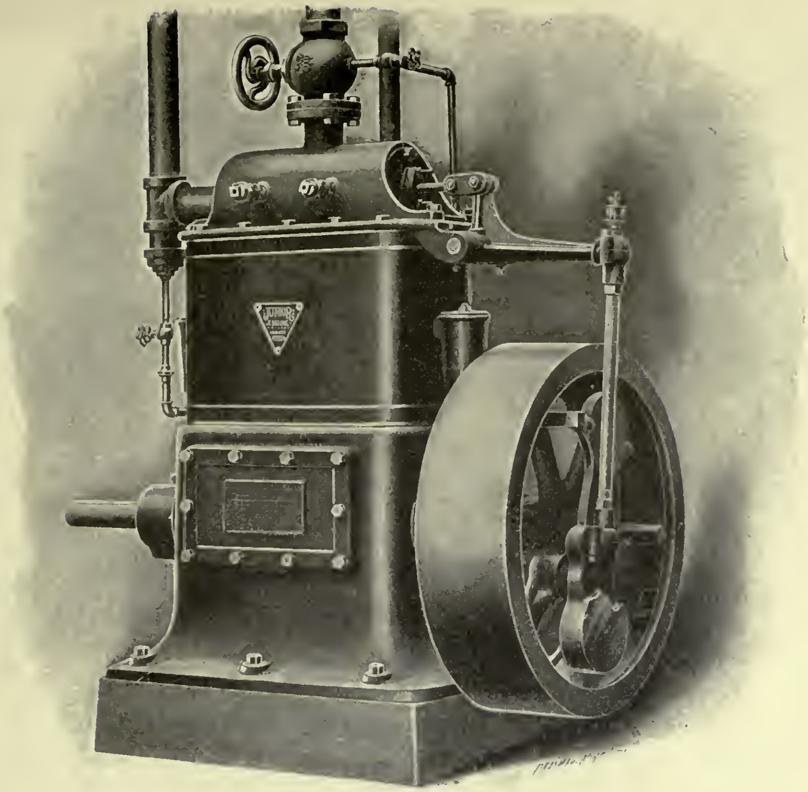


FIG. 34.—Westinghouse Junior Engine.

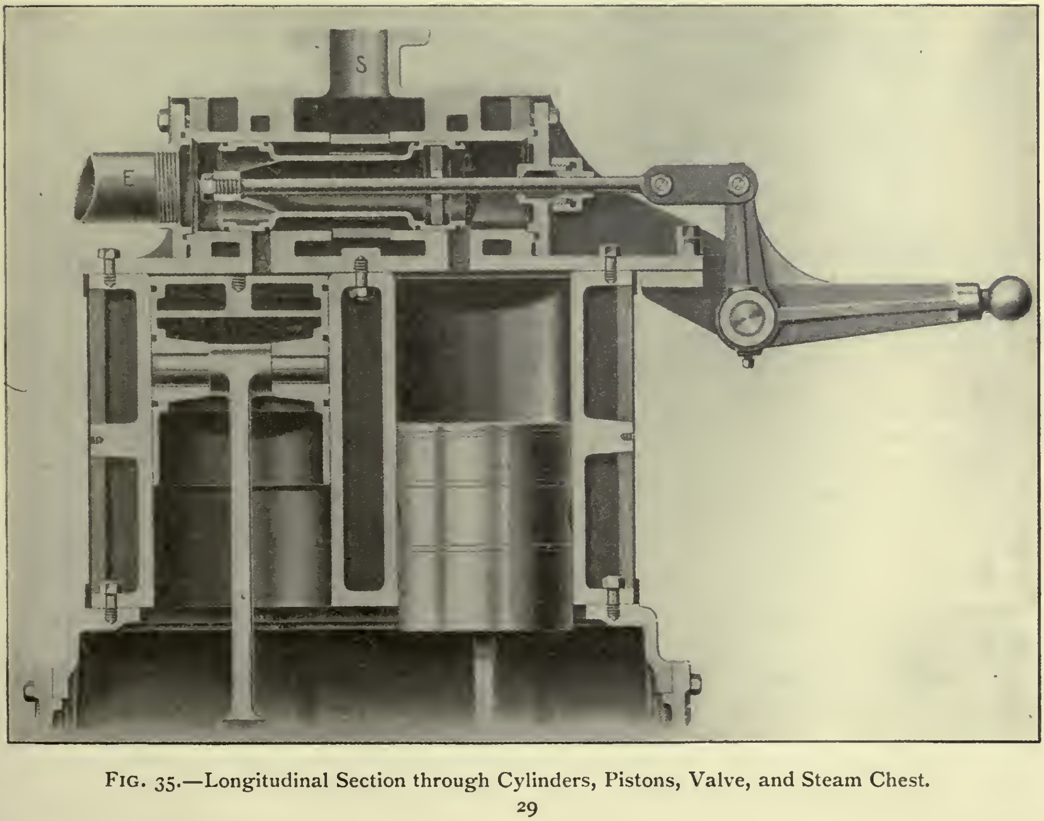


FIG. 35.—Longitudinal Section through Cylinders, Pistons, Valve, and Steam Chest.

valve has begun to uncover the port B, so that the exhaust can pass up and through the valve, which is hollow, to the exhaust pipe E. As the revolution progresses the valve reaches the limit of its travel toward the left and starts back, covering the port A again at a point determined through the governor by the load, allowing expansion to take place in the left-hand cylinder. Continuing its travel toward the right, the valve covers the port B, so that a portion of the exhaust steam is compressed to fill up the clearance spaces. A little later, and just before the revolution is halt completed, the left-hand end of the valve uncovers the port A, so that the exhaust may have free exit when the left-hand piston begins its upward stroke. A similar cycle of operations now occurs in opposite cylinders, completing the revolution.

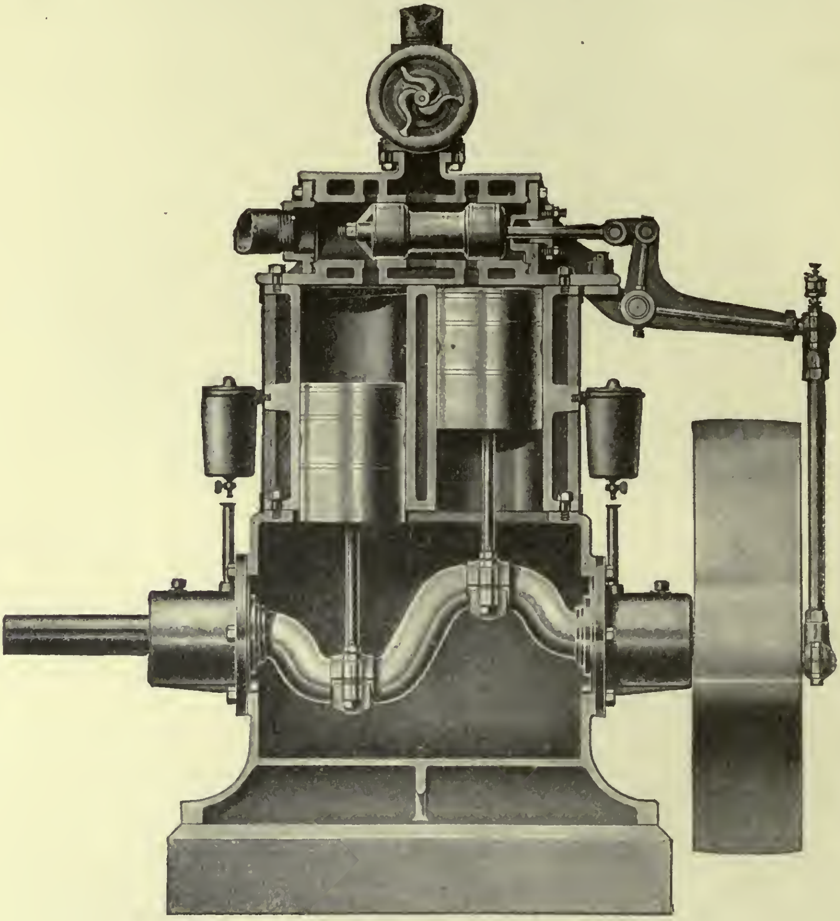


FIG. 36.—Junior Engine. Longitudinal Section.

These engines are made only in small sizes, and, being exceedingly simple, are cheap and not liable to break down.

THE WESTINGHOUSE COMPOUND ENGINE

This is like the Junior engine, but somewhat more elaborate in design to effect the compounding.

As indicated by the sectional figure (Fig. 37), the engine consists in general of a pair of vertical cylinders bolted to the top of the crank case, the latter serving the double purpose of a rigid pedestal for the engine and a receptacle for the lubricating material.

The steam chest is bolted horizontally across the top of the cylinders, motion to the valve being communicated through a bell crank from the governor on one end of the shaft. A driving pulley of suitable size is carried on the opposite end of the shaft. The crank base is filled with water to such a height as to half submerge the crank pin at the bottom of its throw, and on this water is floated about 1 half-inch of heavy black oil.

The cylinders are two plain tubes, without ports or cored passages of any sort, cast together with flanges at top and bottom. The simplicity of the design almost ensures a sound casting. A defect, should any exist, cannot escape detection, as in a more complicated design, and the ease of moulding so plain a pattern would remove any temptation to try to save a bad casting by patching. Both cylinders are bored at one time on a special machine, ensuring perfect parallelism throughout. After boring they are tested for straightness and roundness by means of delicate measurements taken at various points in the bore, with micrometer calipers reading to the one-thousandth part of an inch. They are shown in longitudinal section in Fig. 38, and the low-pressure one in section in Fig. 39.

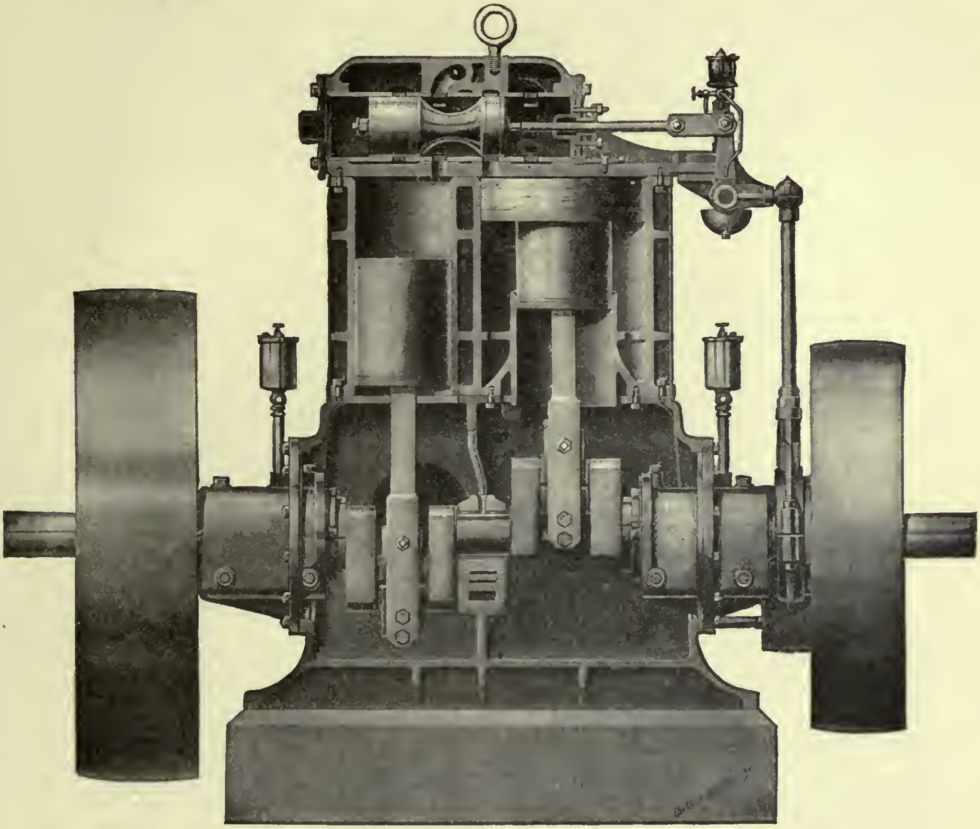


Fig. 37.—Compound Engine. Longitudinal Section.

The steam chest is also a very simple casting, the steam passages being formed by the hard iron bushing which is forced into place after the steam chest is bored out. By this construction the ports can be machined to exact size and register. So perfect are the measurements and records that when a bushing accidentally gets cut, or is worn from long usage, a new one can be fitted with the absolute certainty that it will fit with such nicety that it can be drawn into place with the force that can be exerted by screwing up a 2-inch bolt.

S and E are the steam and exhaust chambers around the bushing, into which

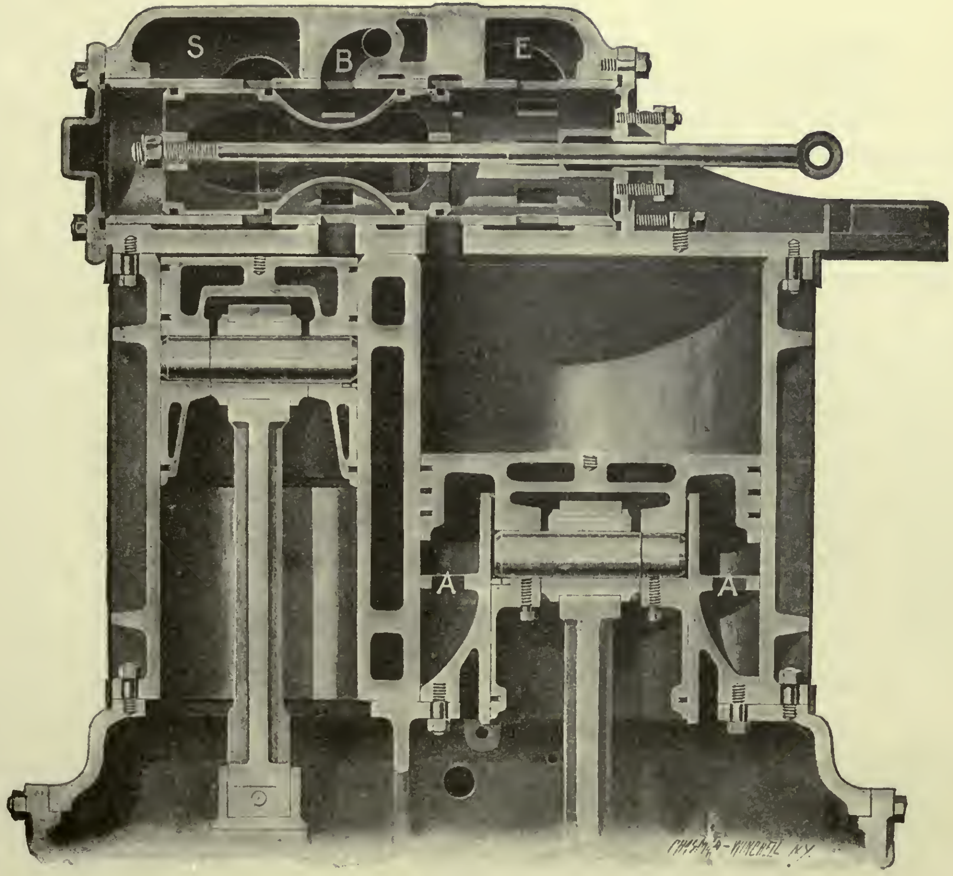


FIG. 38.—Longitudinal Section through Cylinders, Pistons, Steam Chest, and Valves.

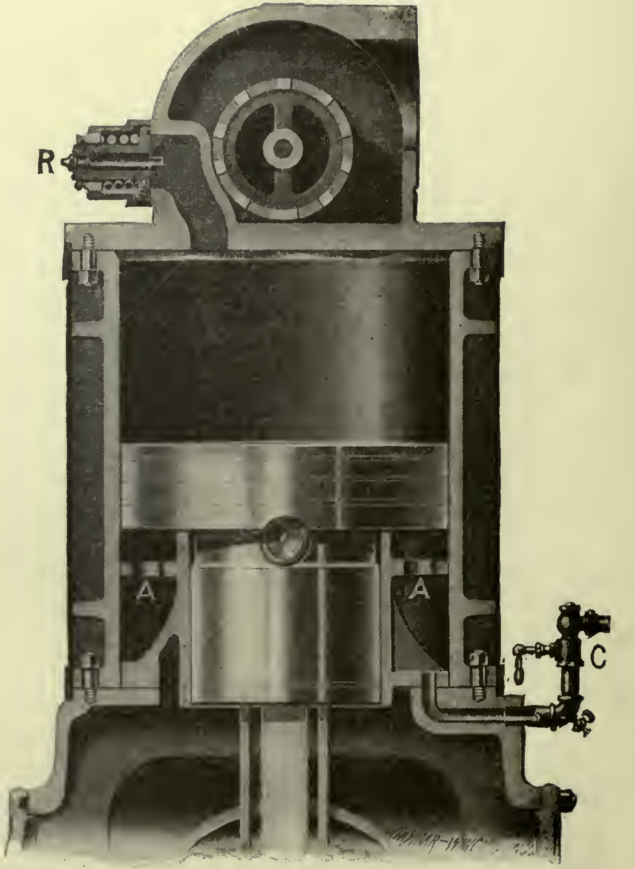


FIG. 39.—Transverse Section through Low-Pressure Cylinder.

connect respectively the steam and exhaust pipes. The curved passage B connects, through the bypass valve, controlled by a hand wheel on the back of the steam chest, with the steam space S. The purpose of this bypass is fully explained in the description of the steam distribution.

On the front of the steam chest are two spring relief valves, one communicating directly with each cylinder, the valve for the low-pressure cylinder being shown in section at R, giving a prompt and free relief for any charge of water that might by accident get into the cylinders. The valve is shown on a larger scale in Fig. 40, the hollow stem being tapped to furnish a convenient point of attachment for the indicator.

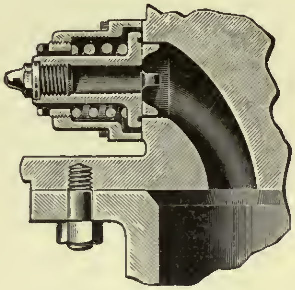


Fig. 40.—Relief Valve.

The main valve is of the piston type, packed with four spring rings. It is tight, and is perfectly balanced under any steam pressure.

The pistons are of well-known trunk pattern, double walled to prevent condensation. The low-pressure piston differs from the high-pressure in that it has two diameters. The larger diameter is that of the low-pressure cylinder, while the smaller is the same as the high-pressure cylinder, and works through a sleeve or internal cylinder fixed in the bottom of the low-pressure cylinder, and centring with it. The object of this construction is twofold: if two pistons of unequal area were in communication with the crank case there would be at each revolution an alternate compression and suction due to the unequal displacement, which would interfere with the level of oil and water, and would tend to blow the lubricant out through the vent pipe. By the construction adopted the displacement of each piston is made the same, and the volume of air in the crank case remains practically constant. The annular space A underneath the larger diameter of the piston and outside of the sleeve forms a cushion chamber, in which the enclosed air is slightly compressed at the bottom of the stroke, and a partial vacuum formed at the top of the stroke. This action, involving no loss of power, assists in absorbing the momentum of the larger piston at the end of the stroke, and materially relieves the crank pin and connecting rod of that duty. This cushion space is drained by a spring check valve C shown in section in Fig. 41. By means of the handle the valve can be held off its seat to destroy the cushioning action when starting or turning the engine over by hand.

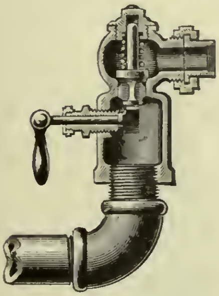


Fig. 41.—Check Valve.

The main bearing is shown in longitudinal and cross sections in Figs. 42 and 43. The bearing proper consists of two cast-iron shells lined with the best quality of genuine babbitt metal. These shells are supported in an accurately machined casting bolted to the end of the crank case, and called the "crank case head." In cases where the shaft is enlarged outside the bearing, or carries an armature which is a forced fit, making it impracticable to slip the bearing off over the end of the shaft, the crank case head is made in halves to facilitate removal. The upper bearing shell is fixed in position by two bolts as shown. The lower shell rests on two wedges, which can be readily adjusted and locked in position by two bolts. The engine being single acting, there is no wear on the upper half of the bearing, so that it acts as a permanent gauge for the true position of the shaft. When any wear is discovered, if the wedges are drawn over so as to bring the shaft up against the upper half of the bearing, it is an assured fact that the alignment of the shaft is perfect, and as the length of the connecting rod does not change with adjustment, that the clearances above the pistons are restored to their normal volumes. This method of adjustment is particularly valuable in the case of direct connected engines and dynamos, to preserve alignment with the outboard bearing, in which the downward wear is almost imperceptible. The end of the bearing is faced off, and has stamped upon it an arrow which indicates the direction in which the wedges are to be moved when taking up wear.

Lubrication is effected by the large sight feed oil cup, the oil being delivered at the top and centre of the bearing, from which point it distributes itself through suitable oil grooves. The surplus works to the outer end of the bearing, where it is prevented from escaping by a ring on the shaft, and is discharged through a cored passage in the under side of the crank case head, into the crank case, fully maintaining the supply at that point. The centre bearing, which is adjustable for height by means of a wedge, is shown in Fig. 44.

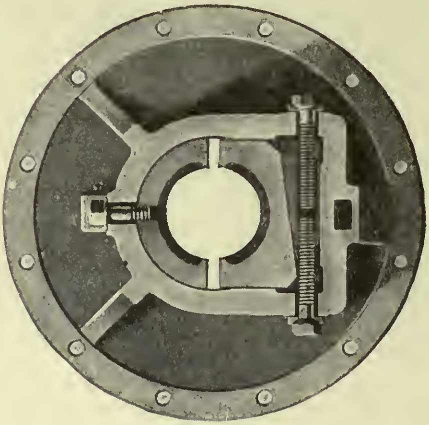


Fig. 43.—Cross Section.

Main Bearing.

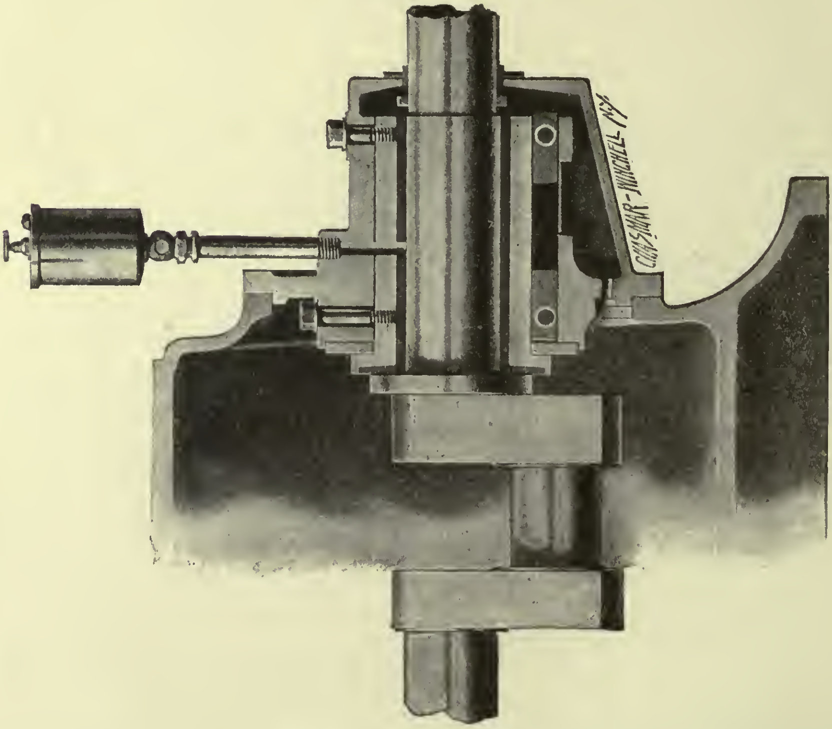


Fig. 42.—Longitudinal Section.

The governor on the compound engine differs but slightly from that on the Junior engine. It is shown in outline in Figs. 45 and 46. It is possible to adjust this governor so that there is no apparent difference in speed whether the engine be running empty or fully loaded, and it is even possible to adjust it so that the speed with the engine fully loaded is 1 or 2 per cent. greater than when running empty. This sort of regulation is a freak, and of no commercial value. Perfect steadiness is the first requisite of a good governor, and a slight falling off in speed with increase of load contributes to that quality. These governors are adjusted to regulate within from 1 to 2 per cent.

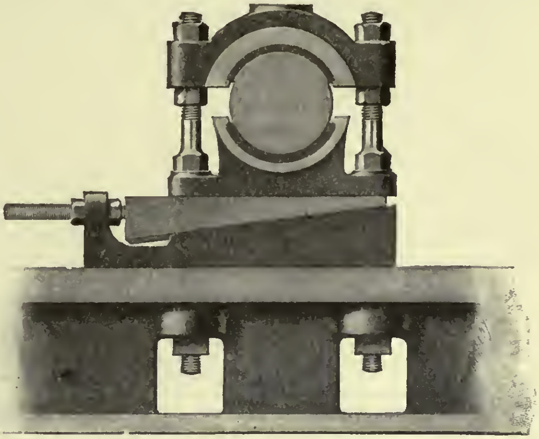


FIG. 44.—Centre Bearing.

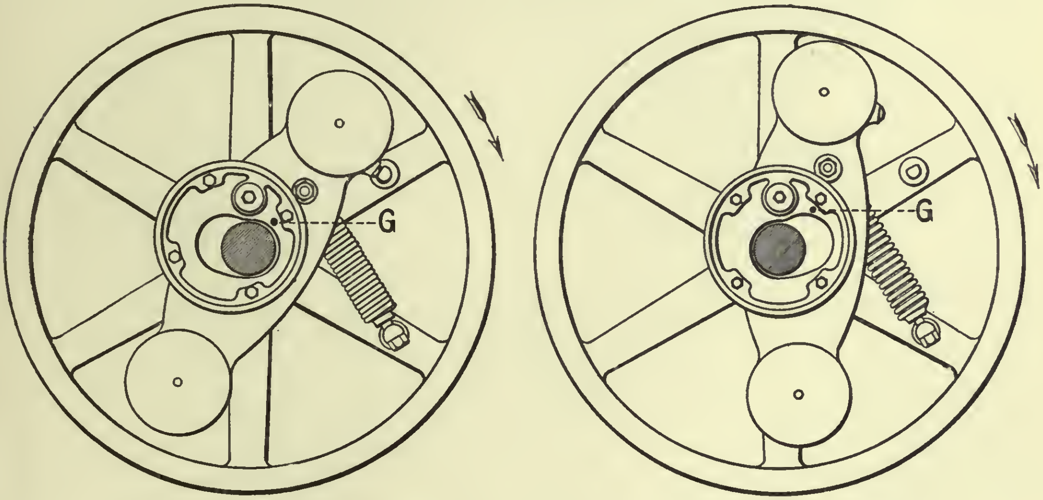


FIG. 45.—Longest Cut-off.

FIG. 46.—Shortest Cut-off.

Position of Governor Parts.

In general the inertia governor consists of a single weight of the typical form shown in Figs. 45 and 46, pivoted on the hub of the governor wheel to one side of the shaft, the centre of gravity of the weight being located approximately at G. A spring with an adjusting screw to regulate the tension is attached to the wheel and the weight at convenient points. Rotation being in the direction of the arrow, any increase in speed tends to make the centre of gravity of the weight seek a position farther away from the centre of the shaft, and causes the weight to swing on its pivot in a direction opposite to that of the wheel. The eccentric is attached to the weight, and this movement brings the centre of the eccentric nearer the centre of the shaft, and increases its angular advance, thus effecting an earlier cut-off. Fig. 45 shows the position of the governor at longest travel and cut-off, and Fig. 46 at shortest or zero cut-off, where the valve travel is just equal to the lap. The greater part of the weight lying outside the pivot, if there be any sudden tendency of the engine to increase its speed, the weight by its inertia tends to lag behind the wheel, thus augmenting or almost anticipating the effect of centrifugal force, and bringing the eccentric to a shorter cut-off. Conversely, if load be suddenly thrown on the engine, and there be a consequent tendency to drop in speed, the weight by its own inertia tends to rotate at the same speed and runs a little ahead of the wheel, swinging the eccentric to a position of longer cut-off. It will thus be seen that in this type of governor, when properly designed, centrifugal force, the primary regulating force, is aided by the inertia of the weight, and the action of the governor is thereby materially hastened.

In the design (Fig. 45) the eccentric is a light removable ring, which can be replaced at small expense if cut or worn; the only bearing requiring to be lubricated is the main spindle on which the weight is pivoted, and this has liberal surface and is provided with ample means for lubrication. The attachment of the spring to the weight is by a hardened steel knife-edge bearing which needs no attention. In the end of the spring is a cast-iron plug threaded to fit the coils, so that the effective length of the spring can be increased or decreased by screwing the plug out or in, decreasing or

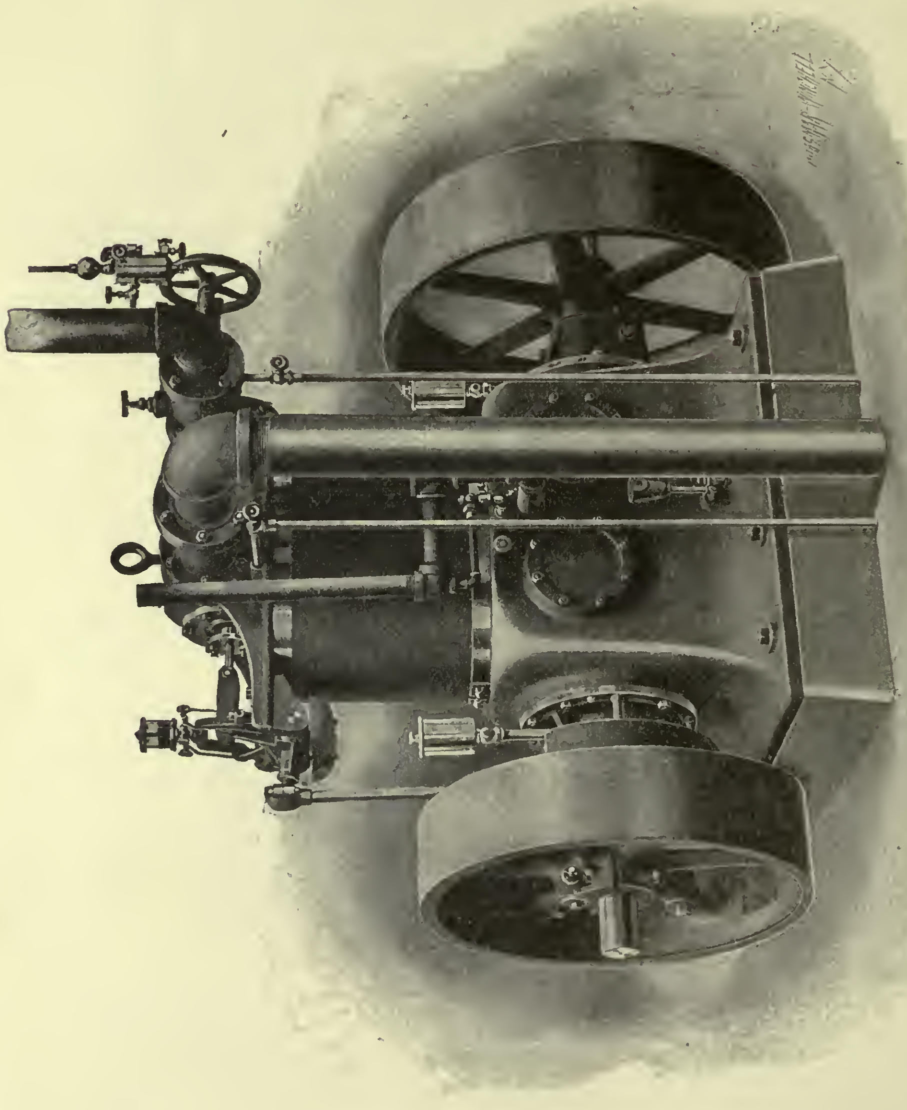


FIG. 47.—Westinghouse Compound Engine. Rear View.

increasing its strength so as to provide for reasonable changes of speed without affecting the closeness of regulation.

The compound engine is shown complete in Fig. 47.

The Westinghouse single-acting engines have been given a rather extended description for several reasons, chiefly because they are highly instructive and represent high-class steam engineering. In the descriptions given every point of interest is emphasised and clearly brought out.

STEAM DISTRIBUTION IN SINGLE-ACTING COMPOUND ENGINES

The steam distribution in the Westinghouse compound engine is particularly novel and interesting, being effected by a single valve instead of from two to eight, as ordinarily used. The principles of compounding are now so generally understood that we need only make passing mention of them. The greatest loss in the steam engine is that due to internal condensation, and the object of compounding is to reduce this loss. As steam enters the cylinder of an engine it first heats up the cylinder walls to its own temperature, and a certain amount is condensed thereby. As the steam expands after cut-off its temperature drops, and if expansion be carried out to any reasonable extent, by the time the exhaust opens the cylinder is many degrees hotter than the steam. Heat then naturally passes from the walls of the cylinder to the steam during exhaust, re-evaporating the water formed by condensation during admission, reducing the temperature of the cylinder walls, and necessitating the condensation of a portion of the next incoming steam. In short, a portion of the steam admitted is instantly condensed before it can do any work, and is re-evaporated after it is too late to do any work, and is wasted through the exhaust.

The higher the initial pressure and the lower the exhaust temperature the greater this loss becomes. For any given initial and exhaust pressures it is practically a constant quantity, and therefore with increasing ratios of expansion it becomes a larger percentage of the steam admitted, so that in the simple engine with a very limited number of expansions the loss from this source begins to overbalance the gain from further expansion. In the compound engine we divide the range of temperature from admission to exhaust between two cylinders, consequently the maximum difference of temperature that can exist at any time between the cylinder and the steam is very much less, and the quantity of heat that can be uselessly transferred is correspondingly reduced. Furthermore, the condensation of the high-pressure cylinder is not wholly loss, as the steam formed by re-evaporation is not wasted, but passes into the low-pressure cylinder, where it does work, or in a measure compensates for the losses in that cylinder.

Take for illustration the case of two non-condensing engines, one simple and one compound, taking steam at 100 lbs. gauge pressure, and exhausting against atmospheric pressure. In the former case the cylinder will be subjected to temperatures ranging from 338° to 212° Fahr., or a difference of 126° Fahr. In the latter case, if we discharge the steam from the high-pressure cylinder into the low-pressure at 30 lbs. pressure, each cylinder will then be subjected to a range of temperature only about half as great. If both engines are using steam with the same number of expansions, and running at the same piston speed for equal powers, the low-pressure cylinder of the compound engine would be practically the same size as the cylinder of the simple engine, and consequently the waste from the former would be only half that from the latter. The high-pressure cylinder of the compound engine having so much less surface, the transfer of heat would be correspondingly less than in the low-pressure cylinder, and what may escape from the high-pressure cylinder is largely in the form of steam at 30 lbs. pressure, which has considerable capacity for doing work in the low-pressure.

The small engravings (Figs. 48, 49, 51, and 52) show the relative position of valve and pistons at four periods during one revolution. The bypass valve, the purpose of which will be referred to later, is for clearness shown in the form of a 3-way cock, and in a closed position, its normal condition when the engine is running.

In Fig. 48 the high-pressure piston is about to begin its downward stroke, and the low-pressure piston is just starting on its return stroke. The valve is moving towards the left, and has travelled from mid position just the amount of the steam lap and lead, and is beginning to uncover the port leading from the steam space S. The right-hand end of the valve, having no lap, has already uncovered a part of the port leading to the low-pressure cylinder. The valve travelling toward the left admits steam from the steam space S into the space around the neck of the valve, and thence through the port into the high-pressure cylinder, driving the high-pressure piston downward; at the same time the crank is forcing the low-pressure piston upward, and the exhaust is passing through the port into the right-hand end of the steam chest, and thence through the passage indicated into the exhaust chamber E, and away through the exhaust pipe connecting with E. When a portion of the revolution has been completed—depending on the position of the governor—the valve has gone to the limit of its travel to the left and returned to a point where it just covers the admission port, cutting off the steam, and is travelling to the right.

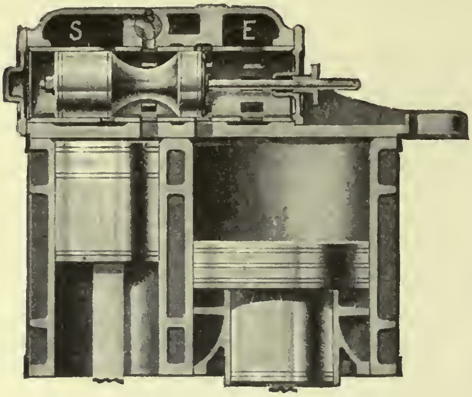


Fig. 48.

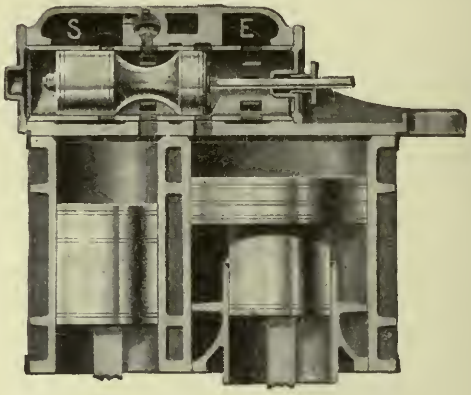


Fig. 49.

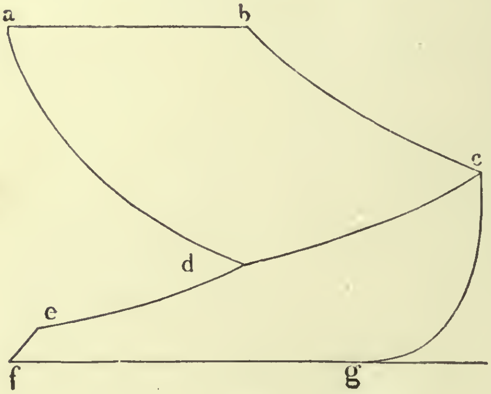


Fig. 50.

The exhaust end of the valve, on account of not having lap, has not yet covered the port, the several parts being in the position shown in Fig. 49.

Referring to the theoretical indicator diagram, Fig. 50, an indicator attached to the high-pressure cylinder would have described the admission line *a b*, while an indicator on the low-pressure cylinder would have described a corresponding portion of the exhaust line *f g*. As the pistons continue their strokes the steam in the high-pressure cylinder and the space around the neck of the valve expands, and the valve, travelling toward the right, closes the port leading to the low-pressure cylinder before the completion of the upward stroke of the low-pressure piston, compressing enough of the exhaust to fill the clearance spaces.

Referring again to the theoretical card, during this period the indicator on the high-pressure cylinder would have drawn the expansion curve *b c*, and the indicator on the low-pressure cylinder would have completed the exhaust line *f g*, and drawn the compression curve *g c*.

On the completion of one-half of the revolution the valve and pistons occupy the positions shown in Fig. 51. The low-pressure piston is commencing its downward stroke, and the high-pressure piston is starting on its return stroke. The valve is travelling toward the right, and beginning to uncover the port leading to the low-pressure cylinder, establishing communication between the two cylinders through the space around the neck of the valve. As the pistons continue their travel the steam is exhausted from the high-pressure cylinder into the low-pressure cylinder, until the valve has gone to the limit of its travel to the right, and come back again so as to cover the low-pressure port and interrupt communication between the cylinders. During this period an indicator on the pressure cylinder would describe the exhaust line *c d* on the theoretical card, and were there no port friction the low-pressure admission line would coincide with *c d*. The steam expands during this part of the cycle, as shown by the drop of pressure from *c* to *d*, by reason of the greater area of the low-pressure piston.

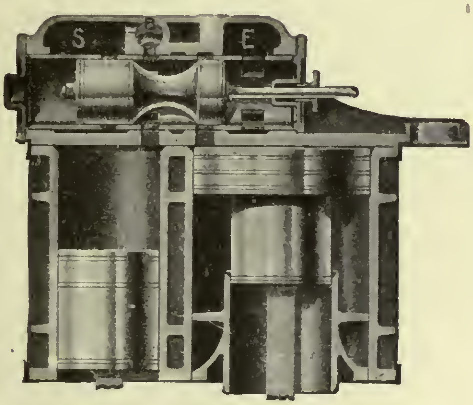


Fig. 51.

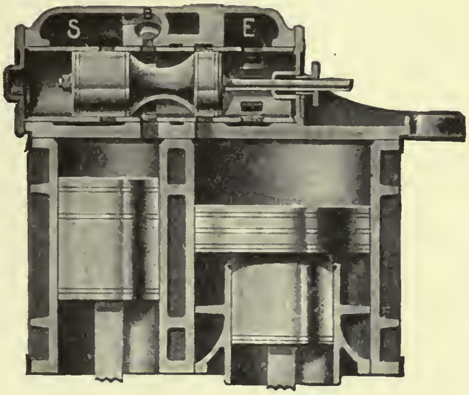


Fig. 52.

The valve and pistons are now in the position shown in Fig. 52, the valve moving toward the left, and the pistons continuing their respective strokes. From this point to the completion of the revolution the steam remaining in the high-pressure cylinder and space around the neck of the valve is compressed up to or near initial pressure, while the steam in the low-pressure cylinder continues expanding until just before the end of the stroke, when the right-hand end of the valve uncovers the low-pressure port for release. During this period indicators on both cylinders would draw lines corresponding respectively to *d a* and *d e f* on the theoretical card, and the valves and pistons would come back to the position shown in Fig. 48, ready to start again on a similar cycle.

The very large high-pressure clearance, comprising not only the port volume and the ordinary clearance between the piston and the end of the cylinder, but also the volume around the neck of the valve, which space is always in connection with the high-pressure cylinder, appears on first thought to be opposed to all ideas of economical design.

This clearance, never being in communication with the exhaust, gives rise to no free expansion losses, and, far from being the bugbear of popular superstition, is really a carefully calculated feature of definitely fixed proportions. It is the secret of the uniform economy of the Westinghouse compound engines under wide ranges of load.

The bypass valve, which as previously stated is for clearness shown as a plain stop cock, is merely a convenience for starting. If the engine is standing with its high-pressure piston at the top of its stroke it can be started without opening the bypass.

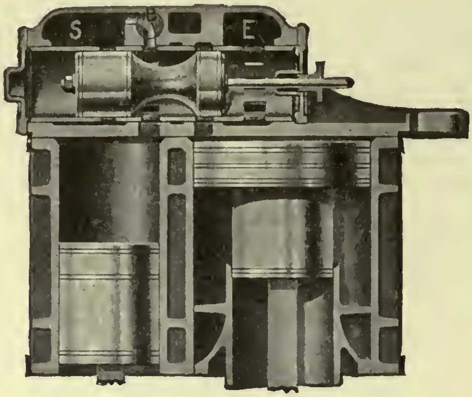


Fig. 53.

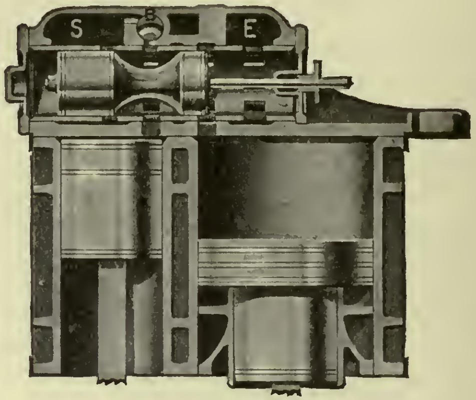


Fig. 54.

If, however, the low-pressure piston should be at the top of its stroke, as in Fig. 51, then the valve is in such position as to close the port which admits live steam, and consequently starting in this position would be impossible. On opening the bypass as in Fig. 53 live steam is admitted to the space around the valve, and as the valve is moving toward the right and uncovering the port to the low-pressure cylinder, as soon as the crank is a little past the centre, steam of the same pressure will be acting against both pistons. Owing to the greater area of the low-pressure piston it will descend, forcing the high-pressure piston upward. On completing half the revolution the valve will have cut off communication between the low-pressure cylinder and the space around the neck of the valve, as shown in Fig. 54, leaving the pressure on the high-pressure piston only, which will consequently descend and complete the revolution. This is the only office of the bypass valve, and it should be closed as soon as the engine is fairly under way, and before the throttle valve is fully opened.

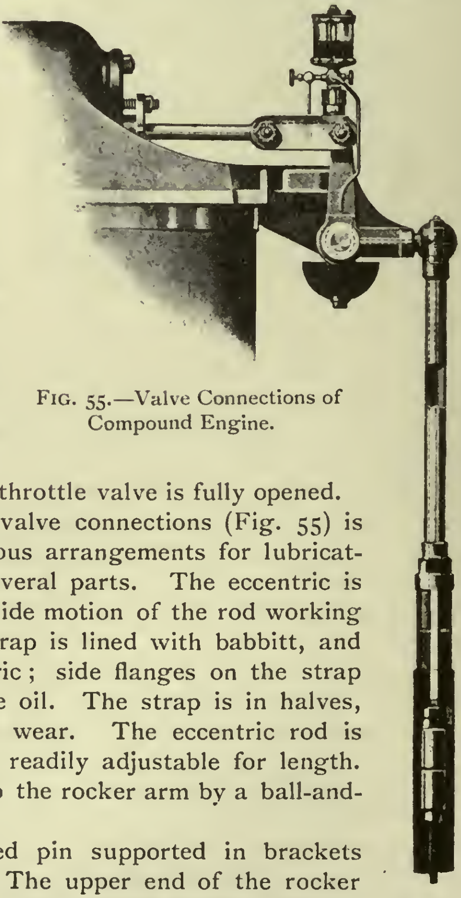


Fig. 55.—Valve Connections of Compound Engine.

The view of the eccentric strap, rod, and valve connections (Fig. 55) is shown more particularly to illustrate the ingenious arrangements for lubricating, but brief mention may be made of the several parts. The eccentric is spherical in form, to compensate for the slight side motion of the rod working on the arm of a bell crank. The eccentric strap is lined with babbitt, and carefully scraped to a bearing on the eccentric; side flanges on the strap embrace the edges of the eccentric, to retain the oil. The strap is in halves, with removable liners at the joint to take up wear. The eccentric rod is hollow, and so attached to the strap as to be readily adjustable for length. The upper end of the eccentric rod connects to the rocker arm by a ball-and-socket joint.

The rocker arm is pivoted on a hardened pin supported in brackets bolted to the under side of the steam chest. The upper end of the rocker arm is connected to the end of the valve stem by two links and hardened pins. All the pins in the valve gear work in removable bronze bushings.

The glass oil cup has three connections. One drops oil in the long groove in the top of one of the valve stem links, indicated by the dotted lines. The link pins are bored out and the ends are plugged, and small holes are drilled at various points on the surface of the pins communicating with the hollow interior. Holes are drilled vertically at either end of the groove in the valve stem link and through the side of each pin, making connection to the hole in the centre. The length of the groove in the top of the valve stem link being greater than the valve travel, the oil from the cup drops into it at regular intervals, is carried to the centre of each pin, and distributed efficiently over the entire surface of the bearing. The two long connections from the oil cup—one being directly behind the other, so that only one can be seen in the elevation—deposit oil in two pockets on the hub of the rocker arm, one on either side of the upright portion.

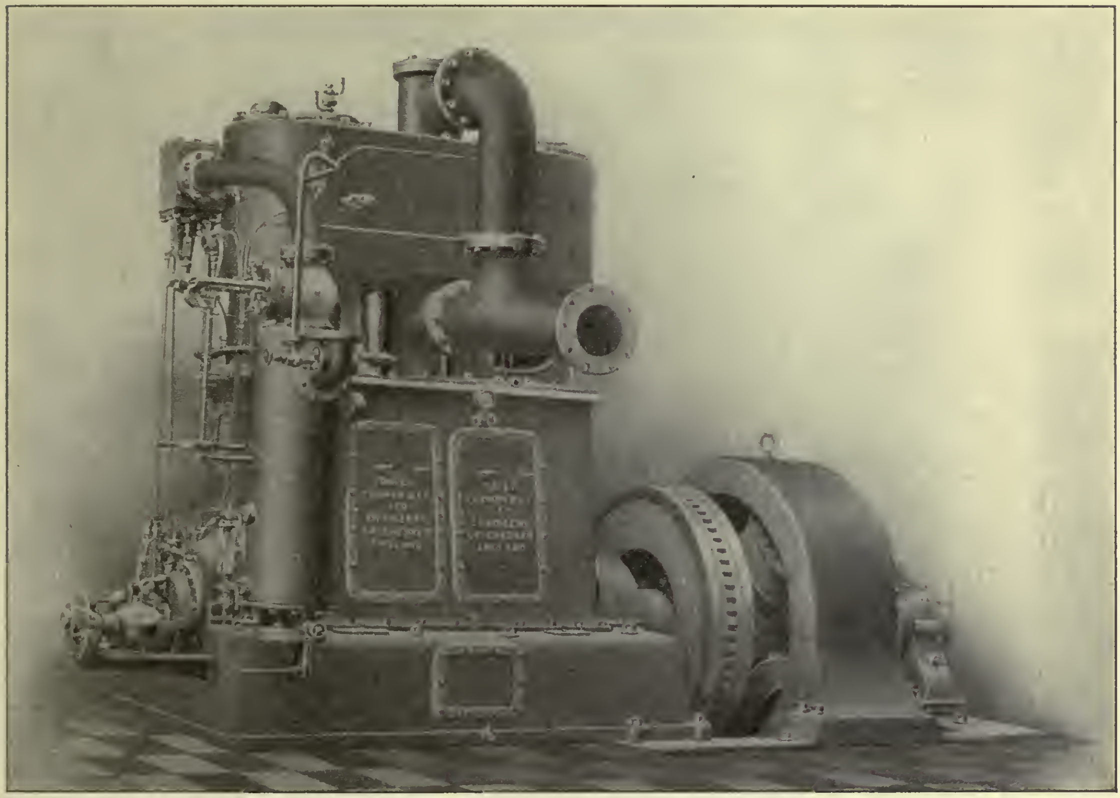


FIG. 56.—Davey-Paxman High-Speed Engine.

From one pocket the oil is distributed through suitable grooves, throughout the length of the pivot pin. The other pocket communicates through a drilled hole, indicated by the dotted lines, with the ball joint. Oil is fed liberally to this bearing, the surplus passing down through the hollow eccentric rod, where it lubricates the eccentric.

Fig. 56 shows the ordinary double-acting type of high-speed engine, as constructed for electrical generators, fitted with a special governor by Messrs. Davey, Paxman, & Co.

The high-speed engine has been fully described, and every type illustrated. They are of passing importance at present, and have developed side by side with the dynamo, and the two together with the steam boiler formed the cheapest producers of electrical energy up till now. But from all accounts, there is no doubt that the gas engine and dynamo have shown a considerable reduction in the cost of electrical energy, so that in the near future the competition between the two prime movers will be keener than ever.

THE ROSSITER HIGH-SPEED STEAM ENGINE

This engine, recently introduced by Messrs. Fullerton, Hodgart, & Barclay, of Paisley, has some features of novelty and merit. It belongs to the single-acting type, Cornish system.

Each type has powerful exponents, and although the relative merits have been discussed at length, it cannot be said that any decision has been arrived at as to which type is the better of the two. One point, however, has been brought out clearly and beyond dispute—the simplicity and economy of the Cornish cycle of steam distribution. But the Cornish cycle cannot be used in a double-acting engine, and this, in connection with other advantages, led to the selection of single action in the design of the "Rossiter" engine.

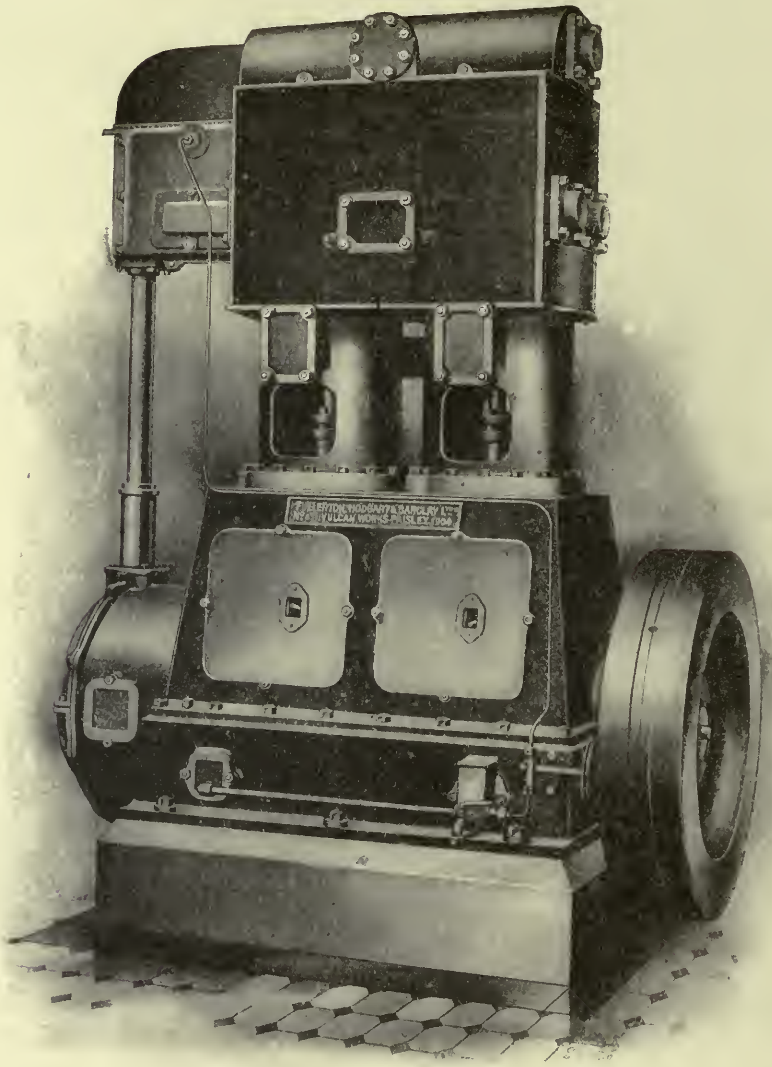


FIG. 57.—Rossiter Engine.

The relative advantages of "cut-off" and "throttle" governing have been fully discussed. Generally speaking, the exponents of "cut-off" governing have confined themselves to "cut-off" governing on the valves of high-pressure cylinders only, because of the mechanical difficulties of applying this principle to the valves of low-pressure cylinders also. Consequently the full advantages of "cut-off" governing have not been properly realised. The design of the "Rossiter" engine, shown in Fig. 57, while embodying the best features of single-acting engines, is peculiarly adapted to governing on the valves of both high and low-pressure cylinders.

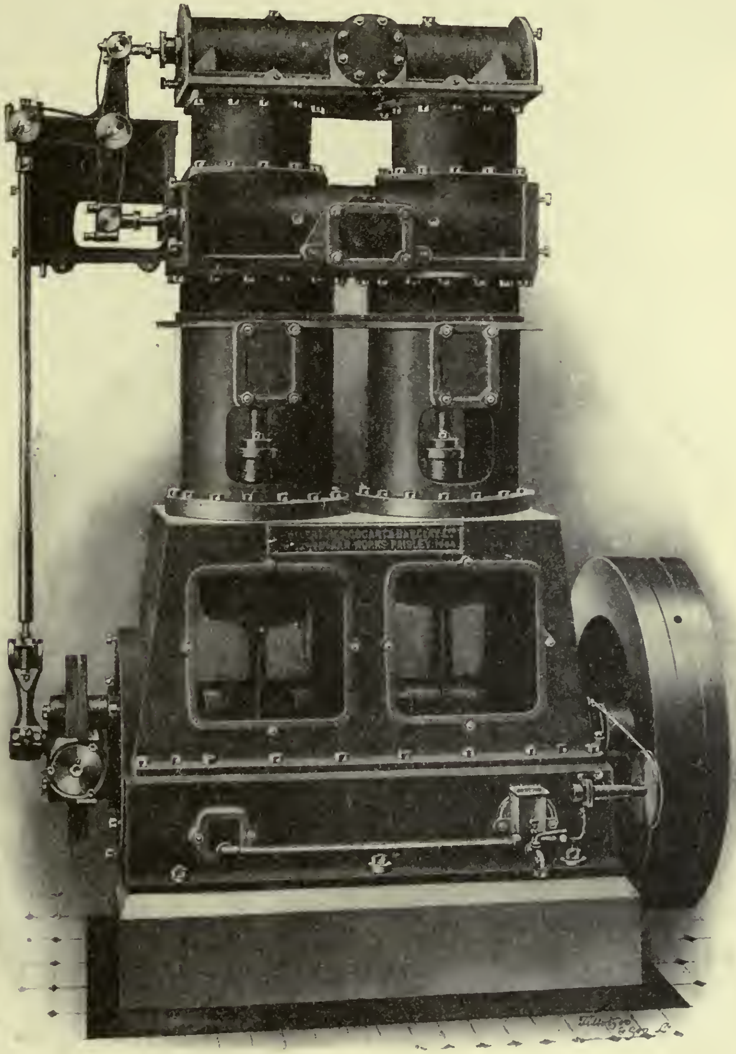


FIG. 58.—Rossiter Engine, with Covers removed.

The engine is vertical, having high-pressure cylinders arranged tandem-fashion over low-pressure cylinders, and the valves, which are of the piston type, work horizontally in steam chests above their respective cylinders (Fig. 59). Steam is admitted alternately to the high-pressure cylinders from between the high-pressure valves, and is exhausted into the cavities on the outside of the high-pressure valves forming portions of the receivers, passing thence through passages at the backs of the high-pressure cylinders to the steam chests above the low-pressure cylinders, which also form portions of the receivers. Steam is also exhausted through ports at the lower ends of the high-pressure cylinders into these receivers, the ports being uncovered by the pistons when at the bottom of the stroke. Receiver steam is admitted to the low-pressure cylinders from the outside of the low-pressure valves, and is exhausted into the cavity between the low-pressure valves, and from thence into a T-shaped pipe which also forms a connection to the spaces below the low-pressure pistons. There are ports in the lower parts of the low-pressure cylinders, and a portion of the exhaust from the cylinders takes place through these ports.

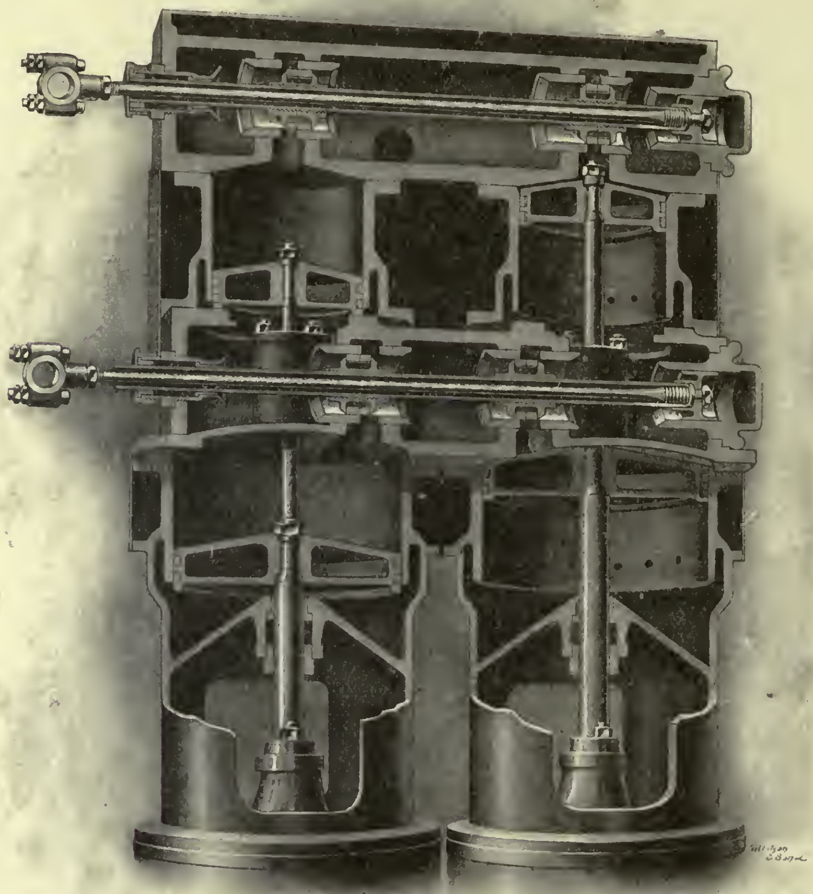


FIG. 59.—Rossiter Engine. Details of Cylinders, Pistons, and Valves.

The drainage of the engine is therefore as nearly perfect as it can be; any water in the high-pressure cylinders being expelled through the ports at the lower ends of the cylinders, and any water entering the low-pressure cylinders being expelled through similar ports into the exhaust pipe.

The action of both the high-pressure and low-pressure valves is controlled by a shaft governor through a common eccentric rod and a three-armed rocking lever

(Fig. 58). At the lighter loads both the cut-off and release of the steam is proportionate to the load, ensuring that the steam is never expanded below the pressure of the low-pressure exhaust cavity. This is an important feature, as in some types of engines where expansion is carried on at light loads to below exhaust pressure any water which may have been retained in the exhaust cavity, instead of being expelled, is drawn back into the low-pressure cylinder.

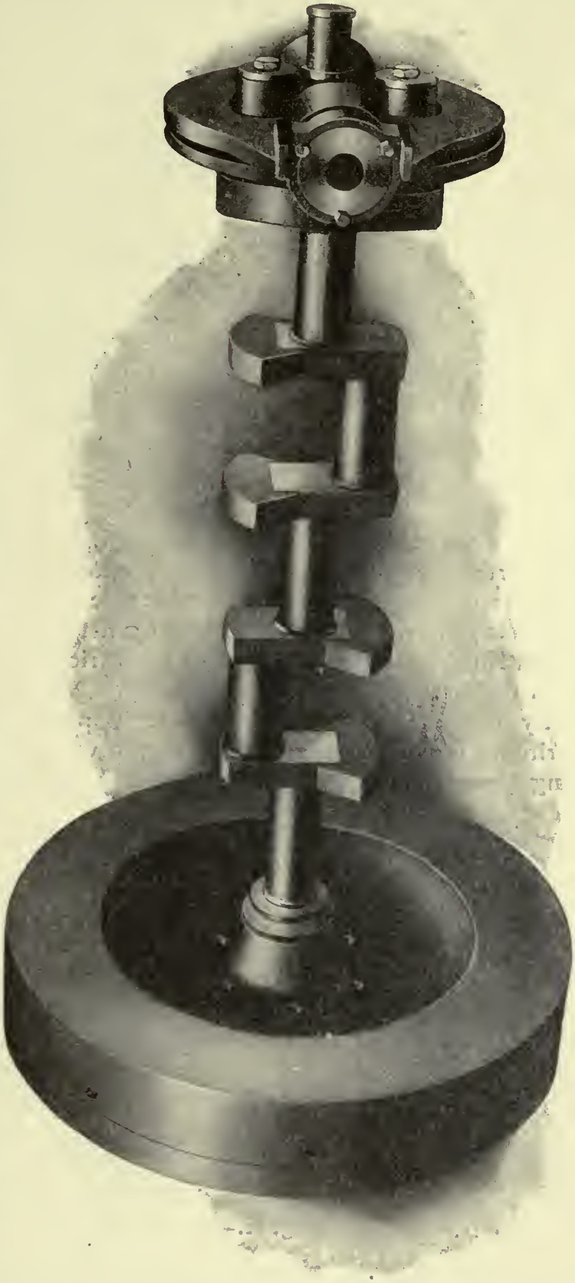


Fig. 60.—Rossiter Engine. Crank Shaft and Governor.

The most important feature, however, is that the receiver pressure is maintained practically constant at all loads, ensuring constant temperature range in both cylinders and receiver, a good economy on rapidly fluctuating loads and the closest possible governing.

The valve nearest the valve door in both high-pressure and low-pressure valves is made of larger diameter than the other. The steam pressure acting upon the different areas causes the high-pressure valve rod to be in tension while the low-pressure valve rod is in compression ; there is a consequent tension upon the eccentric rod, keeping "back-lash" out of the working parts.

Each valve consists of two stout cast-iron rings, made with just sufficient spring to closely fit the liners when new. These rings are backed up by a lap-ended metallic tape. The valve rings are driven by steel discs screwed on to solid-drawn steel tubes, and the annular cavity between the rings and the bosses on the disc is filled with live steam ; in other words, the valves are steam packed, the escape of steam through the partings of the rings being prevented by the metallic tape. The outer ends of the tubes carrying the valves pass through glands, and the tubes are sufficiently long to accommodate long mild steel springing rods firmly secured to the inner ends of the tubes. To the outer ends of these springing rods the rocking lever brasses are fixed, and there is sufficient spring in the rods to admit of the motion of the rocking lever.

The governor (Figs. 60 and 61) consists of two heavy discs, each carried by a suspension pin fastened to a carrier on the crank shaft. The centres of the discs are slightly out of centre with the crank shaft, and as the discs are free to rotate on their suspension pins within certain limits, being the full and no-load positions of the governor, the distances of the centres of the discs moving in opposite directions from the centre of the shaft increase from the full-load position to the no-load position.

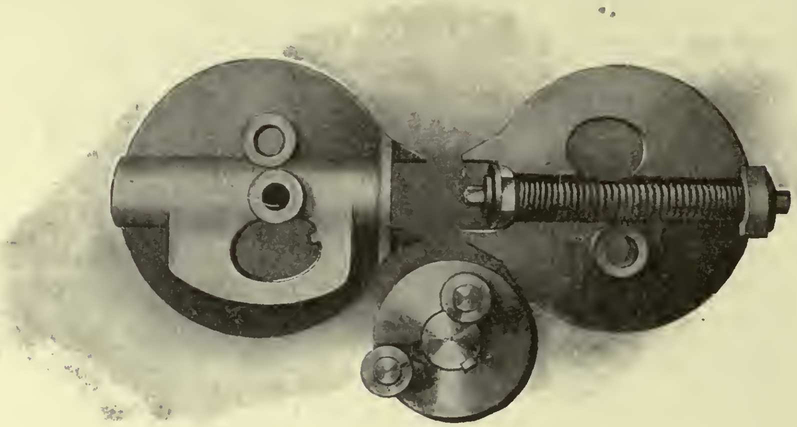


FIG. 61.—Rossiter Engine. Governor.

The discs act like fly-wheels in driving the valve gear, for which purpose the whole of their inertia is available. They are made to act together by means of a guide block on one disc working in guides in the other disc.

Their governing effect depends upon their eccentricity with the crank shaft, and the centrifugal forces due to this eccentricity are balanced by a spring extending across the discs.

By this arrangement an immensely powerful governor is obtained having its centrifugal forces either contained in the weights or taken directly and fairly by the spring in such a way that no unbalanced forces are taken by the suspension pins.

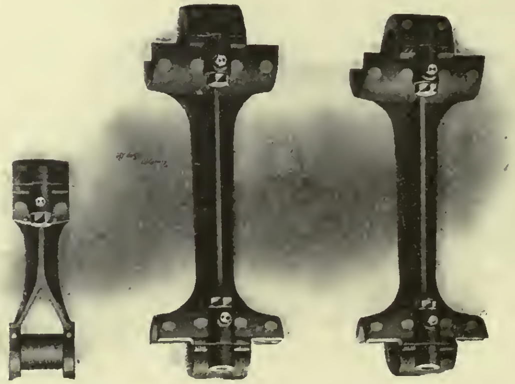


Fig. 62.—Rossiter Engine. Connecting Rods.

The governor is therefore as nearly frictionless as possible, while it is far more powerful in proportion to its size than any other governor on the market. It is immediately affected by any momentary acceleration or retardation, and is balanced about its centre of rotation, and therefore does not impart vibration to the engine.

The engine is very simple in construction, and can be overhauled by any ordinary mechanic without special tools. The whole of the machine work consists of plain boring, turning, and planing, and any part of the engine can be easily renewed without special experience.

By this arrangement of valves the ports, instead of extending half-way round the cylinder as with valves whose axes are parallel with those of the cylinders, terminate on the cylinder cover, thus reducing the clearance to a minimum.

The engine is lubricated by means of oil in the crank chamber. The lubrication of the connecting rods (Fig. 62) and cross-heads is by splash, and the valve gear by means of a small pump fixed outside the crank chamber, which supplies oil under pressure to the valve gear.

Some difficulty has been experienced with splash lubrication, owing to oil creeping up the piston rods and finding its way into the exhaust cavity. This has been obviated by making the distance between the glands at the bottom of the low-pressure cylinders and the top of the crank chamber sufficient to prevent any oily portion of the rod from entering the low-pressure exhaust cavity.

COLLIERY ENGINES.

A good deal of work at collieries can be far better carried out by transmitted electrical power than by small steam or compressed air engines. In all new mines there should be only two engines or groups of engines. An electric generating station should be established to supply electricity for lighting above ground and below; and for driving motors, for pumping, hauling, coal cutting, engineers' shops, saw mill, etc. For this purpose any of the high-speed engines mentioned herein, or in last volume, would be selected.

The winding engines for lifting the coal up the shaft require to be of large power, and under easy and accurate control, continually stopping and starting and reversing. It has been proposed to substitute an electric motor for the steam engine here also, but it is doubtful if that would be any improvement.

It is not a question of economy of fuel. At most collieries there is a quantity of waste slack coal of small value for feeding the boilers. It is rather a question of first cost and maintenance. The first cost would be much greater with electric motor, for the power of boilers and engines would still be the same, but the dynamo and motor would be extra costs.

The switch gear for controlling a 200 horse-power motor by one man, stopping, starting, and reversing every few minutes, has not yet been satisfactorily designed, and will be a formidable affair in any case. There is not likely to be a change from the direct drive of the steam engine to the secondary electric driving of a motor for colliery winding.

All sorts and conditions of engines are to be found at collieries for winding, but in more modern mines the rule is to employ a pair of horizontal steam engines driving the rope drums direct, and controlled by link motion and powerful brakes. In modern collieries the load is lifted at enormous velocities. About midway up the shaft the speed may be at the rate of forty or fifty miles per hour, sometimes more. The engines have therefore to have a large margin of power for quickly accelerating the speed, and so much depends on the safe and regular working of the winding engine in modern collieries that they are now chosen very carefully, and constructed with a very large factor of safety.

An ordinary type of winding engine is shown in Fig. 63. It is geared to the drum so that it may run at a fairly high speed, in order to reduce the dimensions and weight of the engine, a very important feature especially in engines for export to colonies, etc.

The outer gearing is designed with a crank, and the speed still further reduced for working a bell crank pump where necessary to keep the mine dry.

The steam turbine would be the best engine for the electric generating plant at a colliery, but it is useless for winding, as it does not reverse. The same objection applies to gas engines. But gas engines have much to recommend them at collieries for the electric generating plant. The cheap slack coal can be converted into power gas in a gas producer, and with a modern gas engine the power is cheaper than steam, and the trouble and expense of maintaining high-pressure boilers avoided.

In this case it might very well be that a very great advantage could be gained by transmitting all the power electrically, including the winding, and have no steam boilers whatever at the mines. A generating electric plant driven by producer gas, and electric motors to transmit the power above and below ground for all purposes, would be an ideal plant.

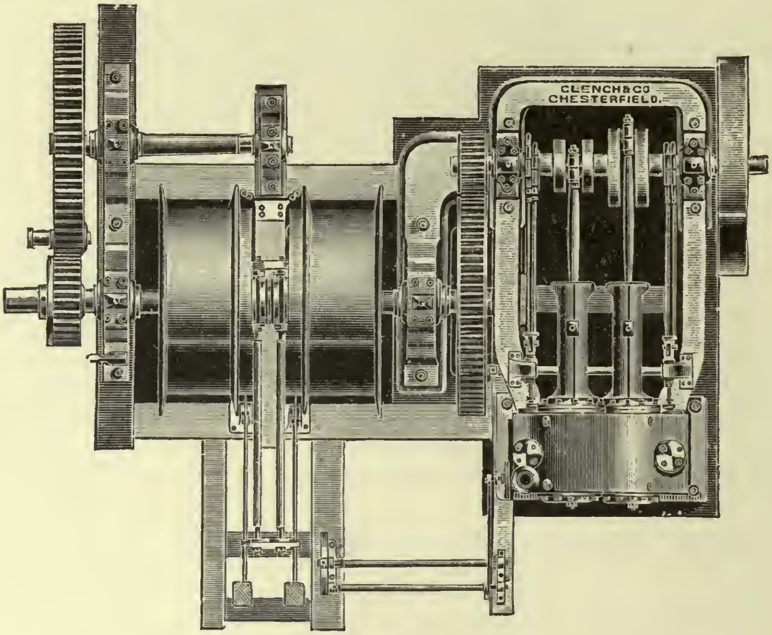


Fig. 63.—Winding Engine.

At collieries where coke is produced the coke ovens or retorts would supply gas sufficient to supply all the power required at a colliery if gas engines, dynamos, and motors were substituted for the steam plant. At anthracite collieries the gas producers would be very simple, as the condensing, washing, and cleaning of the gas produced is a very easy matter compared with the same processes for bituminous coals. In fact, it is better perhaps to coke the bituminous coals, and use the gas resulting therefrom for power, and to sell the coke produced. In any case, there is a very promising field for the scientific and progressive modern engineer to open up in connection with the generation and distribution of power in modern collieries.

Colliery engineering, being more a question of power distribution than one of prime movers, falls to be treated in next volume.

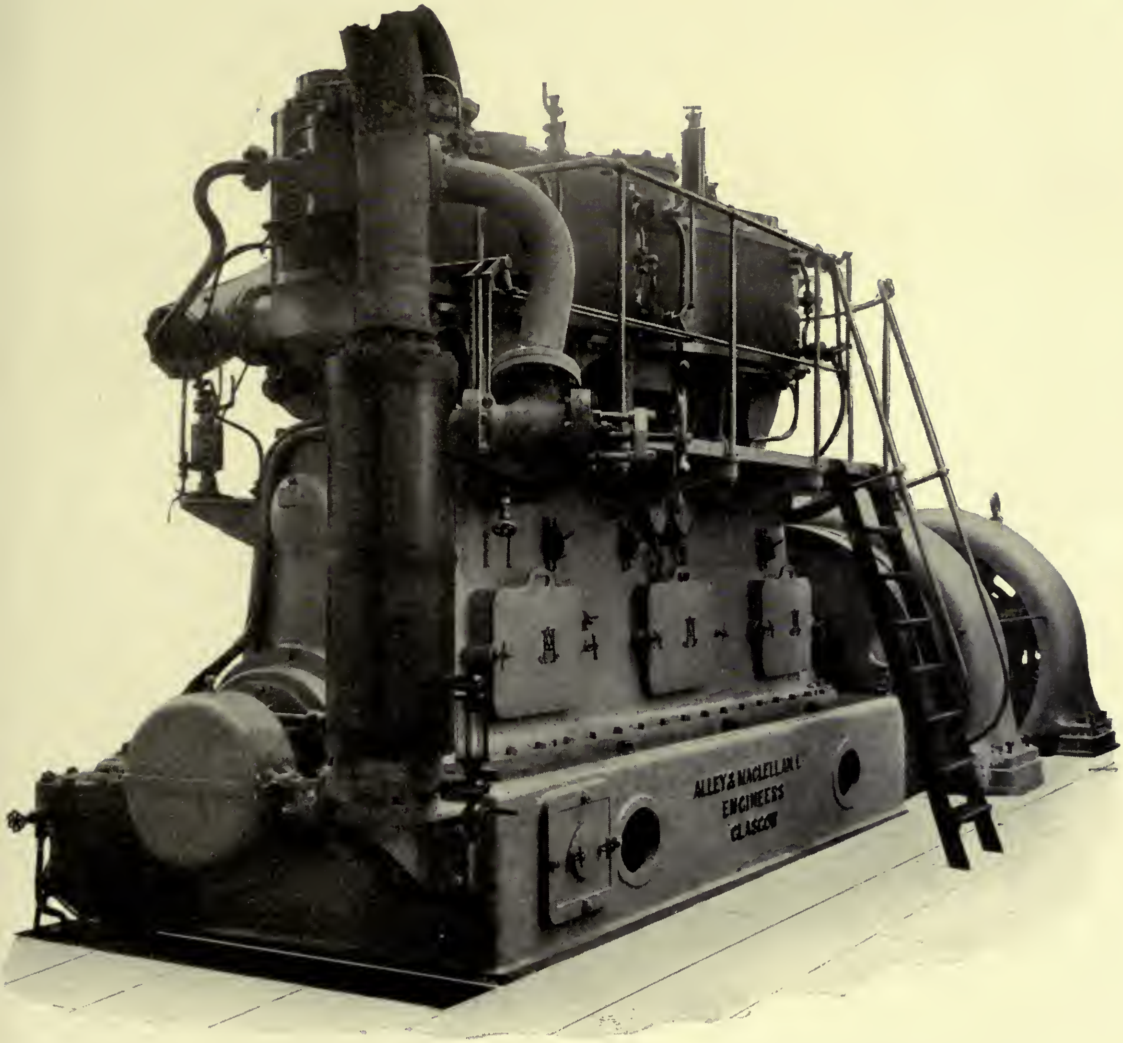

ALLEY & MACLELLAN L
ENGINEERS
GLASGOW

PLATE II.—TRIPLE-EXPANSION DOUBLE-ACTING FORCED LUBRICATION HIGH-SPEED ENGINE.

CHAPTER II

MARINE ENGINES

Marine engines have been classed according to the kind of propeller employed.

We have for Paddle Steamers — the Diagonal Engine; Oscillating Engine; Horizontal Engine.

For the Screw Steamer—the Vertical Inverted Cylinder Engine; Steam Turbine.

For the Hydraulic Jet Steamer—the Steam Turbine; High-Speed Vertical Engine.

The type of prime mover depending somewhat upon the nature of the marine propeller, the propeller itself calls for some notice.

All marine propellers act by throwing a volume or column of water astern. The vessel moves ahead just in the same way as a gun recoils when it throws a bullet. The thrust caused by the engine pushing the water astern is easily calculated if we know the volume or weight of the water driven astern, and its velocity per second. The thrust is equal to $\frac{WS}{g}$, and g is equal to 32.2 feet per second. S is the speed or velocity of the water in relation to still water, and is called the real slip.

This slip is of importance. It was called slip because the screw propeller does not work as a screw would in a solid nut, in which the screw would advance at the rate equal to the pitch multiplied by the revolutions. In water the screw slips so that the speed of the ship is less than that due to its pitch of the screw and speed of revolutions. Similarly, a paddle wheel slips: If it were running on a solid road with a tire on its outer rim the vessel would move ahead at a velocity due to the circumference of the wheel multiplied by its velocity, but in water it slips, and the vessel does not go ahead at a velocity due to the speed of the paddle, but at less velocity. The same thing occurs with the jet propeller and the oar.

Imagine a vessel with a screw propeller towed through the water and the screw at rest, the water will rush through the screw at the velocity of the vessel, say 10 feet per second. If now the screw is revolved by the engine, the velocity of the water passing through the screw would be accelerated, and the water leaving the screw would have some sternward velocity compared with the water around. This acceleration of the column of water passing through the screw is the slip.

With the paddle on a towed boat, the wheel, if free, would revolve at a speed due to the water column coming in front; if the paddle is driven by power it accelerates this oncoming water, and gives it some velocity compared with the water around it.

With a jet propeller freely open, the water in the towed boat would rush through the pipes and jets at the velocity of the vessel, but with no velocity compared with the water outside. If, however, the pump is driven by power the water in the ship will be accelerated, and leave the jet at some velocity compared with the outside water.

This acceleration being really the slip, it is better to use the word acceleration instead of slip, for in the sense of a screw working in a nut it would seem desirable to reduce slip to zero, whereas a screw used as a propeller in water must have slip;

because the smaller the slip the greater the mass of water must be moved to get the same thrust. If the slip was zero the mass of water acted upon would require to be infinite.

The propeller, of whatever kind, must be calculated to give a velocity S to a weight of water W to overcome the calculated resistance of the ship, and from that the size of the propeller and its velocity are found also the power required to drive it.

The speed of the water entering any propeller is called the *velocity of the feed*, and is obviously equal to that of the vessel in the case of paddles and jet propellers. In a screw it is somewhat less, owing to the water following the vessel astern.

The added velocity imparted by the propeller is the acceleration.

The ideal propeller should very gradually accelerate the water from the velocity of the feed to that of the discharge.

A paddle fails in this respect, as it comes down into the water with full velocity, and a great deal of power is lost in churning up the water only; the screw also, but to a less extent, suffers loss from too suddenly accelerating the water.

The jet propeller does not suffer any loss in this respect, for the acceleration is gradually accomplished by the centrifugal pumps if properly designed, and there is no churning or twisting the water. The jet, if properly made, issues in a solid, steady column.

The energy of the discharged water moving astern is lost, and as this energy varies as $W \times S^2$, if we double the quantity of water we double this loss; but if we double the acceleration the loss would be fourfold. From this it can be seen that the acceleration S must be kept down in value, and this means making W large. From this consideration it has been alleged that the jet propeller is at great disadvantage, as it must be limited in the size of jet; but that is a misconception, as I will now proceed to show by taking a case stated by an authority in a discussion already referred to in Volume II. A tramp steamer may be taken to go at 10 knots, or 17 feet per second, with 1000 horse-power indicated, 20 feet loaded draught, 40 feet beam, midship section 800 square feet.

Such a vessel would require a screw of 16 feet diameter, a screw disc of about 200 square feet. There can be no doubt that it is the imagination of this huge column of water behind the screw which leads adverse critics to erroneous and hasty misconceptions on the subject of jet propellers.

In order to make the matter clear the calculations are here reproduced. The thrust given by the engine in both cases may be found by taking the net efficiency as about 0.4, so the thrust or reaction would be $= \frac{550 \times 1000 \times 0.4}{17} = 13{,}000$ lbs.

Now, let us assume the acceleration of the jet propeller equal to the velocity of the vessel. An acceleration which can be demonstrated later on, gives a propelling efficiency of $0.\dot{6}6$. The weight of water required per second can be found by—

$$\frac{W \times 17}{32} = 13{,}000. \quad \text{Hence } W = \frac{32 \times 13000}{17}.$$

Taking sea water as weighing 64 lbs. per cubic foot, the volume of this water would be $\frac{32 \times 13000}{17 \times 64}$. And the area of the entrance or intake of the water would be to let it in at a little more than the velocity of the vessel, $\frac{13000}{17 \times 17 \times 2} = 22.5$ square feet. And as the discharge is at twice the velocity of the vessel, the area of the jet would be half that of the intake, *i.e.* 11.25 feet; and with two propelling jets, each would be only 5.62 square feet, or two jets only about 32 inches diameter.

The screw propeller with its 200 feet of area would not give a higher efficiency than 0.7, and might be as low as 0.63, so that the jet with its 11.25 feet and efficiency $0.6\dot{6}$ does not suffer many disadvantages, from the fact that it works on a column of water so much smaller than the screw.

THORNYCROFT JET PROPELLER

This propeller has been called a screw turbine. It is really a jet propeller in which the pump is a screw pump. It differs from the jet propeller somewhat, in that, part of the thrust is due to the reaction on the screw, about two-thirds of the whole thrust ; and one-third is due to the reaction on the guide blades, which receive the whirling body of water delivered by the screw, and converts it into a straight stream aft. The reaction of the water in being deflected becoming useful thrust, the screw can be run at much higher velocity, in relation to the speed of the vessel, than a plain screw without guide blades. The explanation of this fact is this: the acceleration given to the water by the screw may be greater, because the water, after leaving the screw at a high velocity, enters the guide blades and in passing through them the velocity is reduced, so that although the slip ratio of the screw is higher, a good deal more than that which would be efficient with an ordinary screw, yet by means of the guide blades the velocity of the water thrown astern is not above that required for good efficiency. The energy lost by the water in passing the guide blades is converted into useful thrust on the guide blades. The high slip ratio causes a good deal of rotary motion of the water, which is also stopped and converted into thrust by the guide blades. The hub is fixed to the tube by the guide blades acting like spokes on a wheel. The tube is fixed to or under the stern of the vessel. The passage for the water thrown by the screw is narrowed down by this hub to an area calculated to agree with the slip or acceleration. Thus, if the acceleration is equal to the velocity of the ship, then the contracted area is made half the area of the intake end of the tube. The hub tapers away at the stern, in order to let the water away gradually.

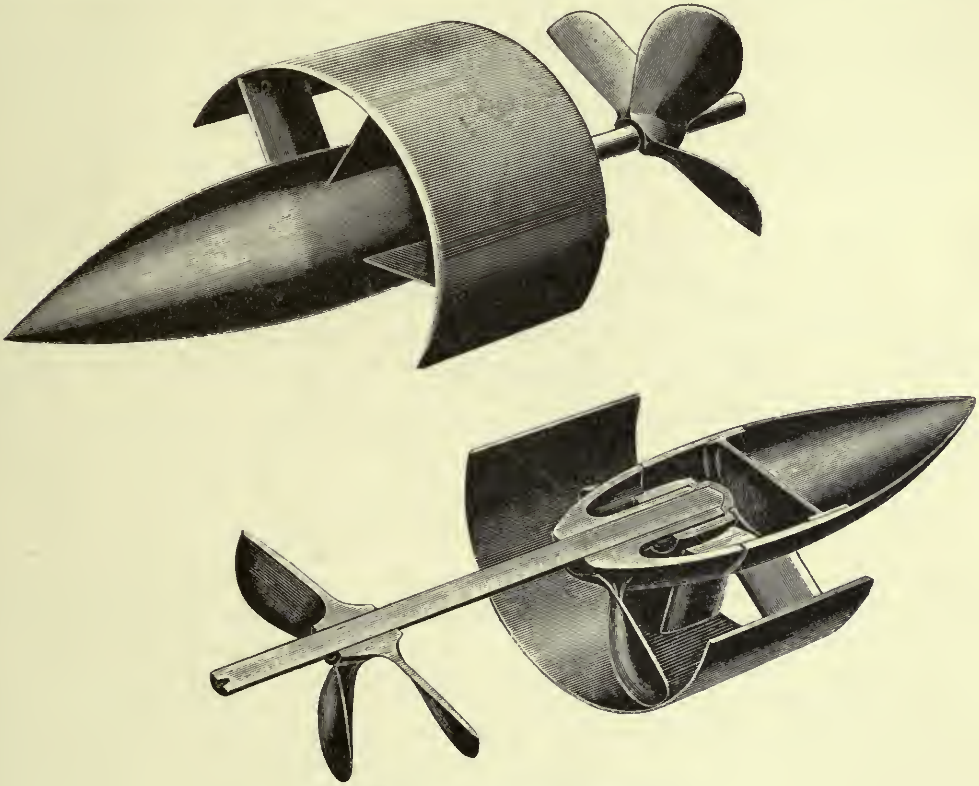


Fig. 64.—Screw Turbine Propeller.

The pitch of the screw at the intake multiplied by the revolutions is only slightly greater than the velocity of the vessel, and increases uniformly to impart an acceleration equal to the vessel's velocity, or sometimes more than that.

The friction losses are somewhat considerable, as it is not possible to put in highly efficient guide blades in a water stream having a compound motion; whirling and moving in a line parallel to the axis of the whirl, the reversing screw also causes frictional losses when going ahead.

Instead of placing the screw pump outside, the author has employed it in connection with his hydraulic jet propeller, using it merely as a pump inside the vessel. It is therefore possible to use a small screw at a high velocity to get a much greater thrust than with an ordinary screw. An ordinary model screw 12 inch diameter gives about 12 lbs. thrust; at an efficient acceleration or slip a screw with guide blades properly shaped and placed, of equal diameter, gives 26½ lbs. thrust. Another one of same diameter, but less efficient, gave 32 lbs. thrust.

A screw with guide blades is like the jet propeller, it does not require to deal with a column of water of the large diameter required by the screw alone. A screw with a disc arc of 5.6 with guide blades is at the same efficiency equal in thrust to a plain screw with a disc area of about 16 square feet—the diameter of the one being 32 inches, the other 54 inches. It is therefore suitable for shallow vessels of shallow draught.

It has the drawback that it is not reversible. A separate screw is required of the ordinary type for going astern. The blades of this screw are of the same pitch as the leading edge of the other screw, and advance without propelling when going ahead, and give a thrust sufficient for the astern movement when the engines are reversed.

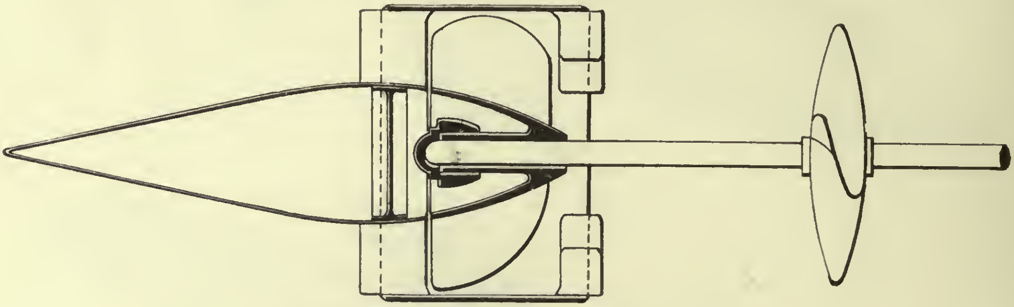


FIG. 65.—Screw Turbine Propeller. Section.

The propeller consists of a tube as shown in Fig. 64, in one end of which is the screw propeller, in the other end the guide blades with a biconical centre. The propeller is shown in Fig. 64 partly in section, with the reversing screw. Fig. 65 is a part sectional elevation. Fig. 67 a view of the inlet showing the screw and the straight blades in front to prevent rotation. Fig. 66 shows the outlet end with the curved blades, and the central block.

If the slip of a screw were constant at all speeds, the sternway screw would be inoperative at all speeds ahead; and this is so nearly the case that it is anticipated that, if the pitch be adapted to the speed at which the slip is least, the sternway screw will not retard the vessel appreciably at any speed. In the case of a vessel used for towing varying loads, when the slip will vary as the load, the sternway screw will at times do part of the work of propelling.

Mr. Thornycroft holds the view that the power to go astern is not of first importance in a steam vessel, and he has even proposed to do away with the complication of reversing gear in the marine engine, holding it to be expensive and cumbersome; and although used but seldom, the parts comprising it are at work during the whole time the vessel is under way. Mr. Thornycroft points out that the power of reversing motion is not possessed by even the fleetest animals. Nature provides means for stopping and turning quickly, but not for going astern. Seamen have, however, departed so far from the old sailing ship days, when it was necessary to check the way of a vessel in good time, and have become so accustomed to facilities afforded by a reversible engine, that they are dissatisfied with a propeller that will not back a ship. It is in indulgence of this weakness in the modern mariner, and to meet other requirements, that the sternway screw has been devised. There might be fewer accidents if marine engines were not reversible; but this would be because fewer things would be attempted. For instance, the Thames 'tween-bridges passenger traffic, the New York ferry services, and many other services of this nature would be impossible.

The sternway screw was tried on the *Goodwill*, a vessel built for the Baptist Missionary Society, and is said to have answered its purpose admirably.

From a paper by Mr. D. W. Taylor, U.S. Navy, recounting a series of experimental tests upon screw propellers, the results of which are somewhat remarkable. In giving higher efficiencies than we have been accustomed to, the author of the paper considers that perhaps the most remarkable feature of these results is the disclosure of the fact that as the pitch ratio is decreased the influence of the area of blade upon the results become progressively less, until for the propellers of very fine pitch ratio the narrow blades actually absorbed the greater power. For the propellers of 0.6 pitch ratio, curiously enough, at a slip of 26 per cent. it makes practically no difference what the width of blade is, the same power is absorbed by the propeller, although the narrow blades show somewhat greater efficiency. Below this slip the narrower blades absorb the greater power, just as for the 0.4 pitch ratio, while above this slip the wider blades take more power. As pitch ratio is increased this action becomes less and less, until for the higher pitch ratios experimented with the power absorbed is greater the wider the blade. The increase in the power with increasing width of blade is, even for the high pitches, however, much less than it should be according to propeller theories.

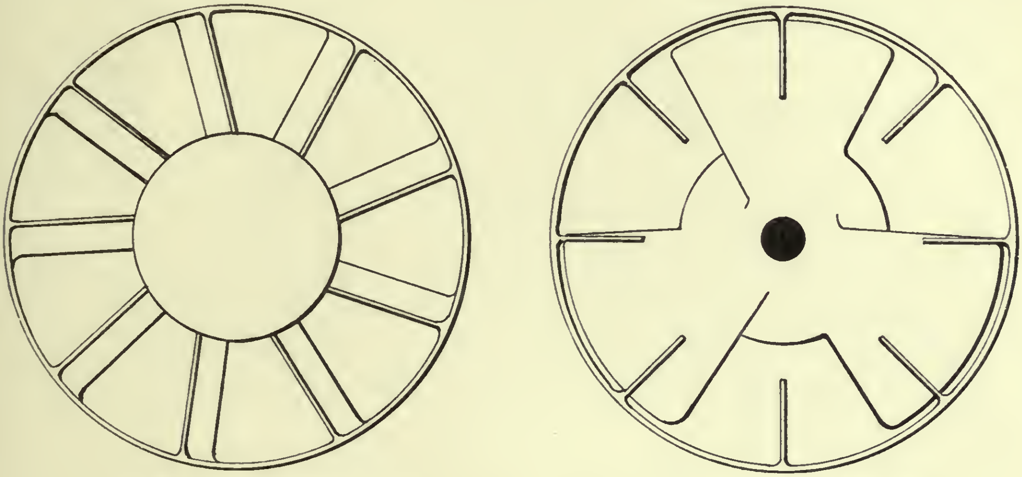


FIG. 66.—View looking forward.

FIG. 67.—View looking aft.

Screw Turbine Propeller.

Another remarkable feature is the fact that as the pitch ratios of the propellers decrease, the power absorbed and efficiency at low slips are both very great, the slip being based upon a conventional pitch. Thus, considering the series of propellers, it was seen that for the narrowest blade the efficiency at zero slip is 66.8 per cent., while the maximum efficiency of this propeller is but 67.4 per cent. As the blade width is increased this effect is decreased. Of course, an explanation of the features above described is the fact, already pointed out, that the slip based upon conventional pitch is necessarily erroneous. It would seem that the real or effective pitch of the propeller was a quantity which varied very much. For small slips the effective pitch would seem to be very much greater than the nominal pitch, whereas for large slips it would seem to become less again. In other words, at small slips the propeller acts as if the following portion of the back of the blade was predominant, whereas at large slips it acts as if the leading portion of the back of the blade assumes predominance.

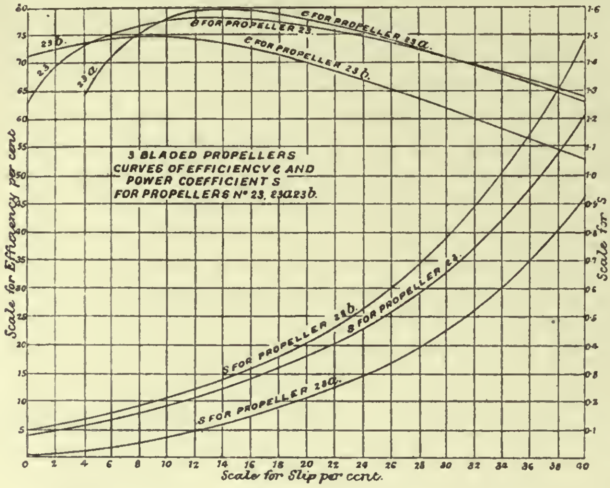


FIG. 68.—Results of Experiments on Special Shapes of Propeller Blades.

The paper goes on to show in Fig. 68 the effect of shape of blade section. These refer to three propellers—Nos. 23, 23*a*, and 23*b*. No. 23 was one of the regular series, 16 inches in diameter, 19.2 inches pitch, 64.7 square inch blade, and 0.200 mean width ratio. Nos. 23*a* and 23*b* had the same diameter and blade area, but had sections as shown in Fig. 69. The pitch of the lines A, A for 23*a* was 19.2 inches. In other words, the face and back of the blade were similarly convex. For 23*b* the pitch of the portion *a–b* of the face of the blades and the portion *c–d* of the back of the blade was the same—namely, 19.2 inches. Fig. 68 shows together the curves of efficiency and S for these three propellers. It is seen that for propeller 23*a* there is a slight gain of efficiency as compared with No. 23—the usual shape—but a marked falling off in the power utilised. At the slip corresponding to maximum efficiency 23*a* can utilise only about 50 per cent. as much power as No. 23. Propeller 23*b* shows a falling off in efficiency as compared with 23 and 23*a* except at very low slips, but has somewhat more capacity for utilising power than No. 23. Propeller No. 23 was also run reversed, with the backs of the blades driving. The results are not shown on the curves, but the maximum efficiency shown was not as great as 50 per cent.

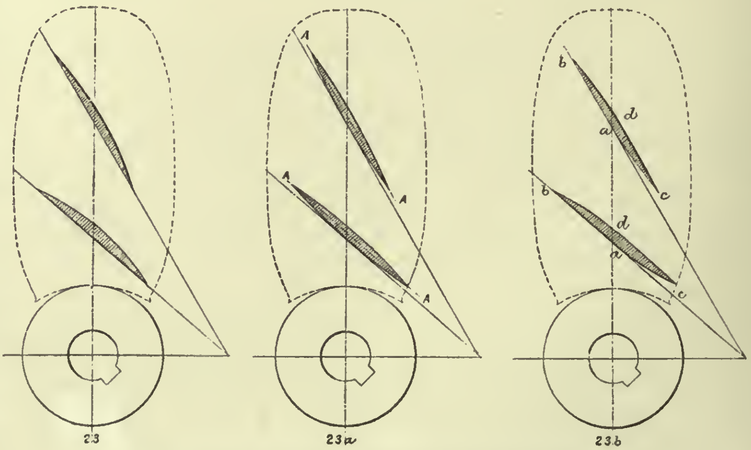


FIG. 69.—Special Shapes of Propeller Blades.

Fig. 68 illustrates strongly that the shape of blade section is a very important factor in propeller performance. It should be noted in this connection that fine pitched propellers should have as high a value of S as practicable, in order to keep down the diameter and increase the pitch ratio.

S is a symbol employed in the paper to represent the power coefficient.

These results, on the whole, only prove again that the true action of a screw propeller is difficult to predict.

THE PADDLE WHEEL

Is quite as efficient as the screw or jet propeller, but its speed of revolution is slow, necessitating large and more expensive engines. It is now only used for very shallow draught engines, stern wheelers and side wheelers.

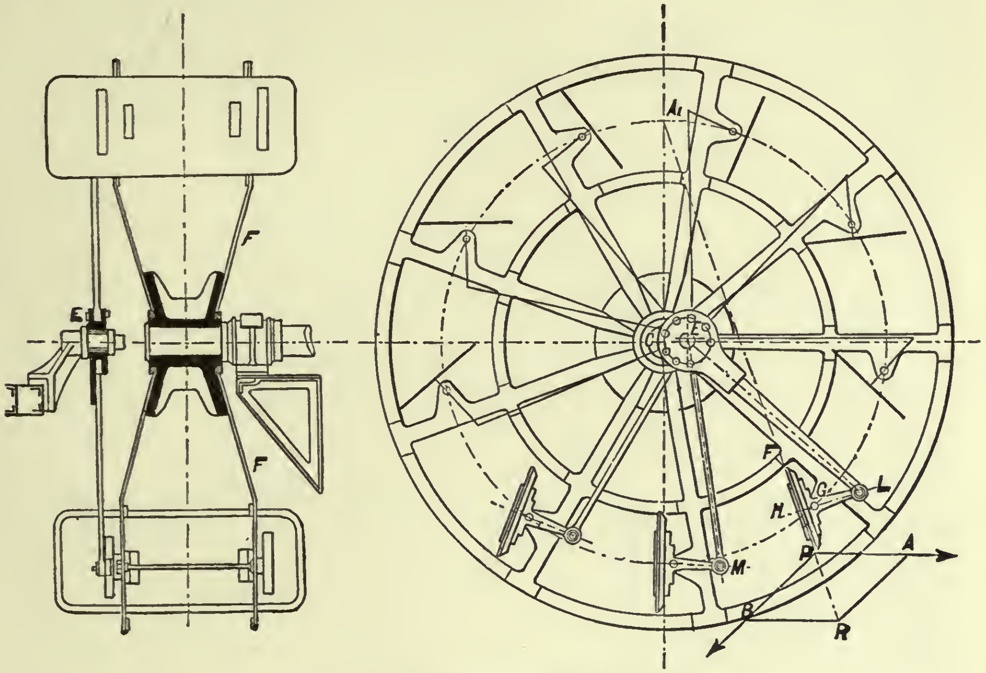


FIG. 70.—Feathering Paddle Wheel.

Feathering floats are now usually employed. Their action and general construction may be gathered from Fig. 70, a transverse section and side elevation.

THE PADDLE ENGINES

These are vertical, horizontal, diagonal, or oscillating.

The oscillating engine (Fig. 71) is little used, but it takes up very small space in a boat; and even a fairly long stroke engine can be put into a comparatively shallow paddle-wheel vessel. Fig. 71 shows it as constructed by Messrs. John Penn & Sons. The cylinder oscillates upon hollow "trunnions," through which the steam is admitted to and withdrawn from the valves—the piston rod by this means accommodating itself to the motion of the crank without any "parallel motion" being required. This construction of engine is efficient for small river boats, in which it originated.

THE VERTICAL OR STEEPLE ENGINE

So called on account of the steeple-like guides above the cylinder projecting above deck. It is shown partly in section in Fig. 72, showing the air pump. They are only to be used in the case of river steamers, where the increased height of the centre of gravity, and the increased surface exposed on deck to the action of the winds and waves, are not so detrimental as would be the case in a sea-going steamer.

THE DIAGONAL ENGINE

So called from the engine being inclined at an angle, so as to keep it well down in the vessel. This design is by far the best for moderately shallow draught vessels and with paddles. It is shown in diagram in Fig. 73, and Fig. 74 shows Messrs. Campbell & Calderwood's compound diagonal engine of most modern design.

The illustration (Fig. 74) shows a triple compound surface-condensing diagonal paddle engine, and represents the type of engine for use in light draft paddle steamers, where economy of fuel, combined with high speed, are the most important considerations.

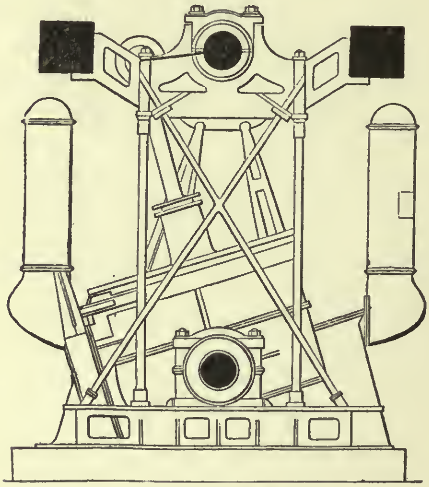


FIG. 71.—Oscillating Engine.

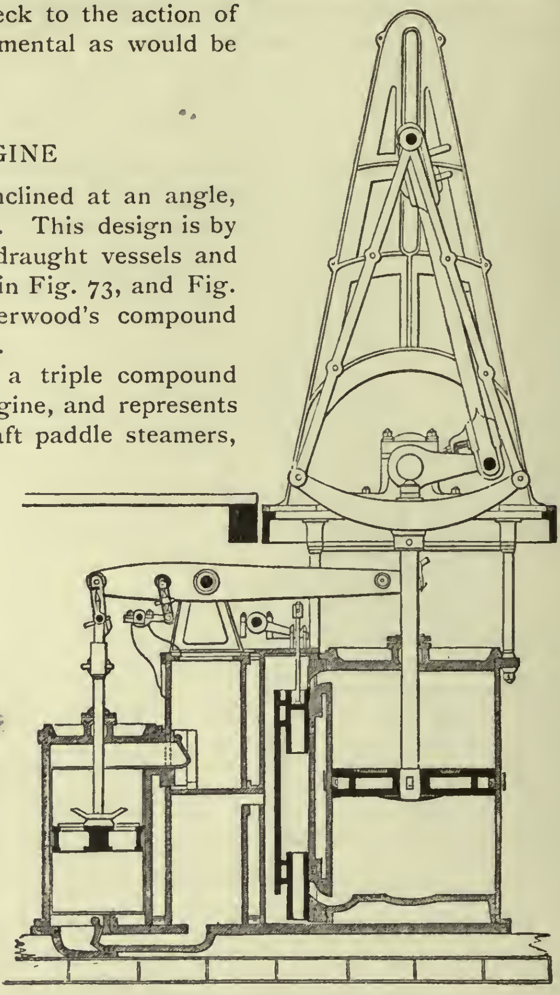


FIG. 72.—Steeple Engine.

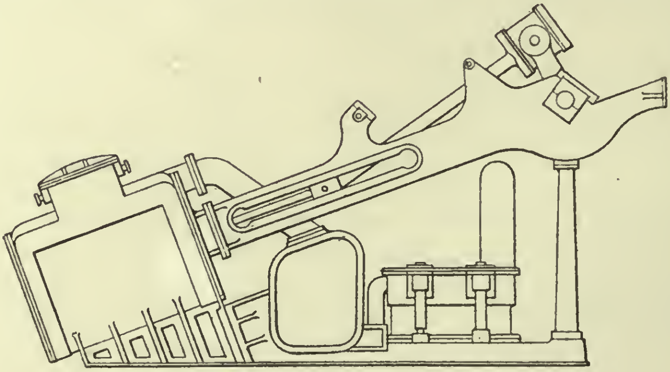


FIG. 73.—Diagonal Engine.

The cylinders as arranged in this engine have the intermediate between the high and low-pressure, but the arrangement of these may be optional, the high-pressure cylinder being at times preferred in the centre. The high-pressure cylinder is fitted with a piston valve, the other two cylinders are fitted with flat valves, and the cylinders are covered with felt and teakwood staves, and fitted with escape valves, drain cock, starting valves, throttle valve, and indicator cocks.

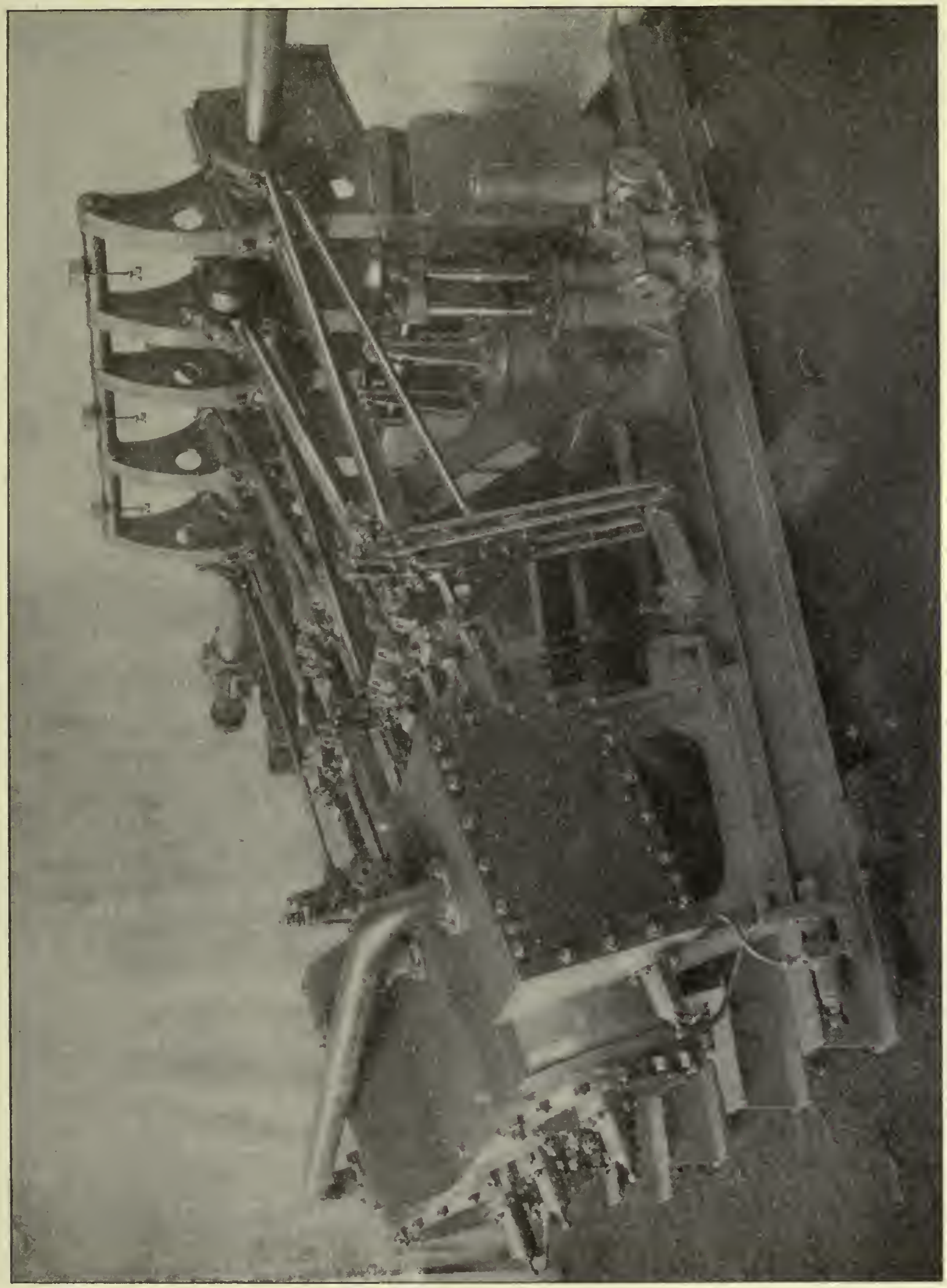


FIG. 74.—Triple Compound Diagonal Paddle Engine.

Air, feed, and bilge pumps are worked from links and levers from high-pressure cross-head, and the water is circulated by improved centrifugal pump with independent vertical engine. The condenser is strongly ribbed, and has provision on top for taking the pillow blocks ; the tube plates are of muntz metal, the tubes of best solid drawn brass, and the packing consists of screwed glands with cotton cord.

The piston rods are guided with mild steel stay bars, which are securely bolted to cylinders and pillow blocks. The framework at base of engine is of cast iron strongly ribbed, and has provision for starting engine and pumps cast thereon.

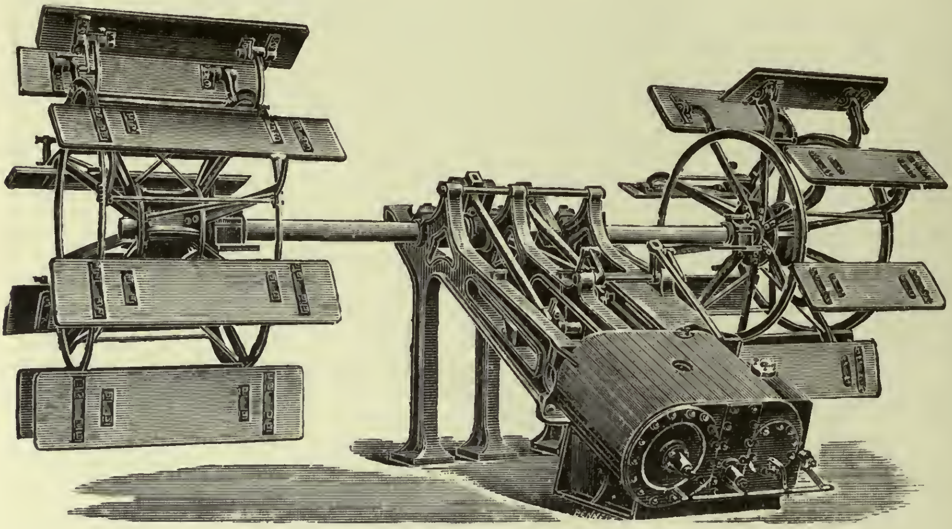


Fig. 75.—Simple Diagonal Engine.

The valve gear is of the usual double-eccentric type, and adjustable at all the principal working parts. Starting engines are fitted to the larger sizes.

The paddle wheels are of the feathering type, strongly got up, and have large bearing surfaces. The centres are of cast iron, and the outer pillow blocks, which are of cast iron, are lined with white metal.

The indicated horse-power given in the table is the approximate power with 160 lbs. working pressure per square inch.

No.	Diameter of Cylinders.	Stroke.	I.H.P.	Revolutions.	Weight, with Pipes, etc.
1	10 ins., 16 ins., 26 ins.	24 ins.	95	50	10 tons.
2	11 ,, 17½ ,, 28 ,,	27 ,,	125	50	13 ,,
3	12 ,, 19 ,, 31 ,,	30 ,,	170	50	17 ,,
4	13 ,, 21 ,, 34 ,,	33 ,,	225	50	22 ,,
5	14 ,, 22 ,, 36 ,,	36 ,,	280	50	27 ,,
6	15 ,, 24 ,, 39 ,,	39 ,,	350	50	33 ,,
7	16 ,, 25 ,, 41 ,,	42 ,,	420	50	40 ,,
8	17 ,, 27 ,, 44 ,,	45 ,,	520	50	48 ,,
9	18 ,, 28 ,, 46 ,,	48 ,,	600	50	55 ,,
10	19 ,, 30 ,, 49 ,,	51 ,,	725	50	65 ,,

Fig. 75 shows a simple non-condensing marine engine and paddles by the same firm. The engines are of a type specially suited for paddle steamers, where a small first cost and economy of fuel are essentials. As the boilers for this type of engine should be supplied with fresh water, they should only be adopted where an ample supply of fresh water can be obtained. These engines, when fitted with radial paddle wheels, have few working parts, and are special favourites where skilled labour is scarce. The valve gear is of the usual double-eccentric type, with starting gear conveniently arranged on deck. The cylinders are covered with hair felt and polished teak, and fitted with drain cocks, escape valves, throttle valves, and lubricators.

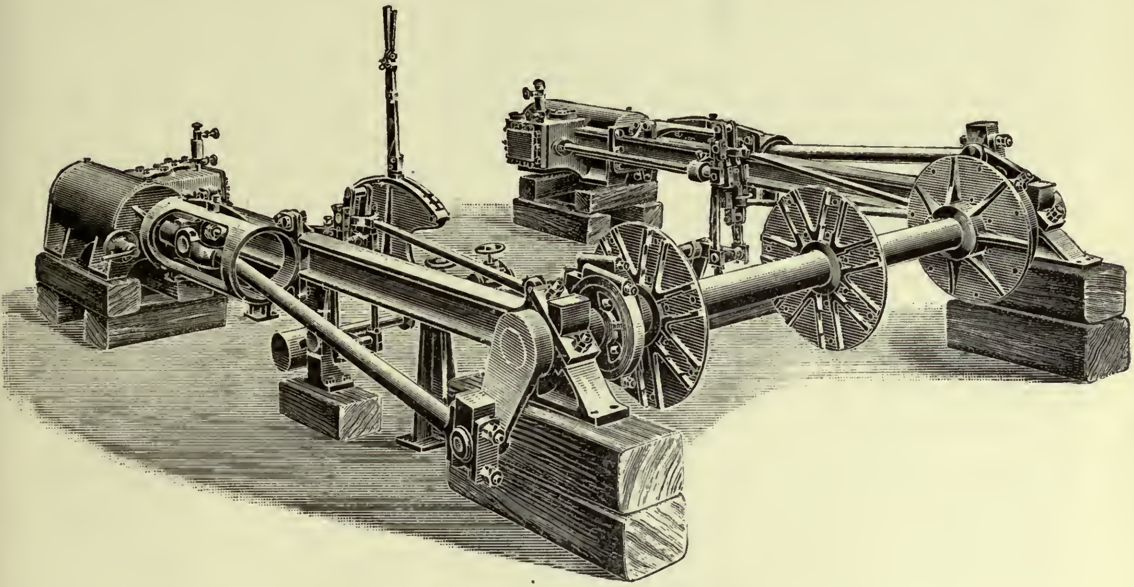


FIG. 76.—Simple Stern Wheel Engine.

The crank shaft is of mild steel of the built type, and polished all over; the pillow blocks at crank are fitted with gun-metal bushes, and the outer pillow blocks are lined with white metal. All bearings are of ample surface, to ensure satisfactory working at full power, and the principal working parts are adjustable.

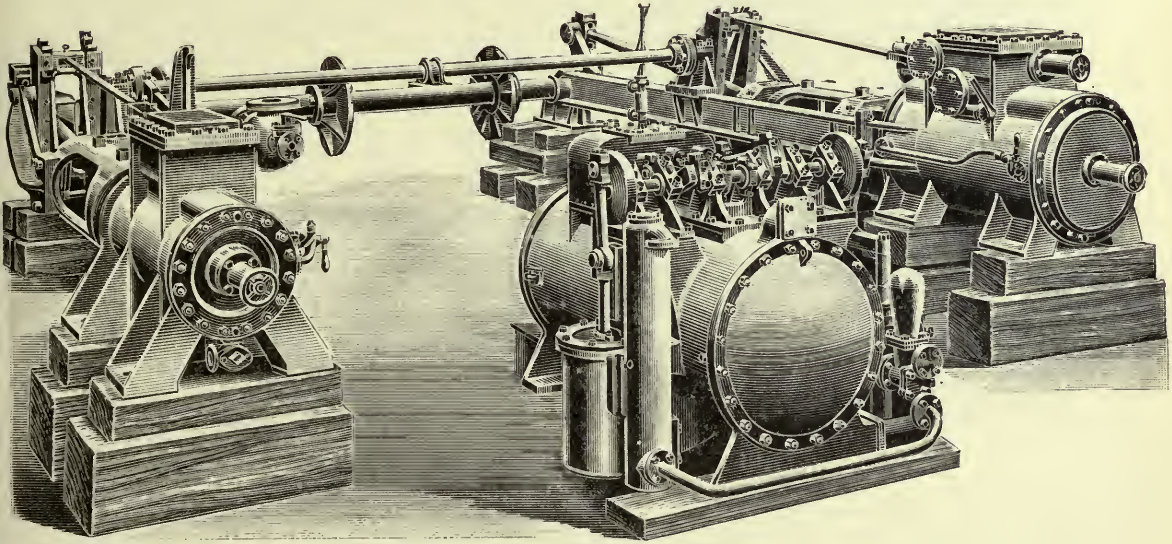


FIG. 77.—Stern Wheel Condensing Engine.

The stern wheel, which was the first of all propellers, is still in use on very shallow waters. A simple stern wheel engine is shown in Fig. 76. These engines are arranged on each side of the vessel, with one radial paddle wheel between. This is a favourite arrangement; it reduces the first cost, and where the stern of the vessel is kept fine they are equally efficient. A condensing stern wheel engine, with valve gear of Joy's radial type, is shown in Fig. 77.

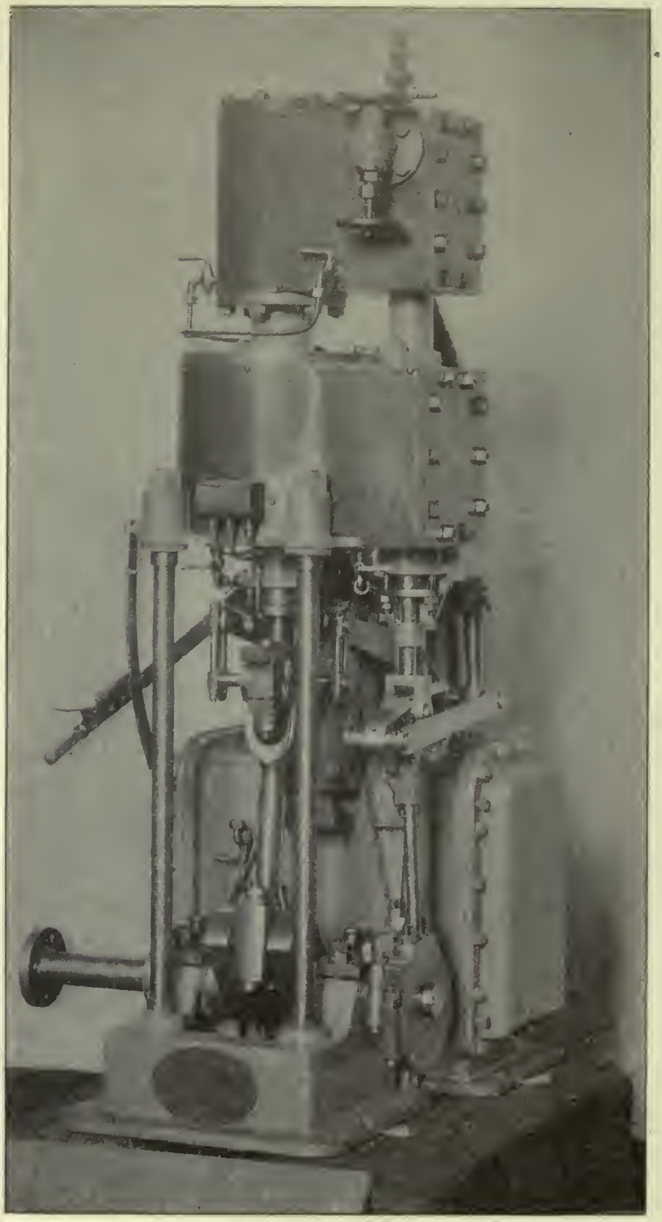


FIG. 78.—Tandem Screw Engine.

The paddle shaft is of best mild steel, with a steel polished crank shrunk on each end, and the paddle wheel is attached to strong cast-iron centres, the number depending on the breadth of the wheel. The cylinders are of sound, tough cast iron, fitted with flat slide valves, escape valves, drain cocks, indicator cocks and pipes, throttle valve, steam-starting valve, and sight-feed lubricator. They are covered on body and casing with felt and polished teak staves securely held in place. The condensing apparatus is entirely apart from main engine, and the air, circulating, feed, and bilge pumps are driven by an independent 2-cylinder engine. The condenser is of cast iron of circular form. Tube plates of muntz metal, tubes of solid drawn brass, packed with screwed glands and cotton cord packing.

As stern-wheel steamers are only adopted where a light draught is essential, the strongest and best materials are used in the construction of this class of machinery to reduce the weight. Steam pressure, 150 lbs. per square inch.

In steam lighters or small screw steamers, where space is an important desideratum, the tandem type of screw engine illustrated in Fig. 78 is recommended.

These engines are of the surface-condensing type, and are very compact. The condenser is arranged vertically, and has substantial provision for attachment to the low-pressure cylinder and sole-plate.

The cylinders are supported on the front side by two steel polished columns, thereby making the working parts very accessible.

No.	Diameter of Cylinders.	Stroke.	Revolutions.	I.H.P.	Weight, complete.	
					Tons.	Cwts.
1	14 ins. and 28 ins.	3 ft. 0 ins.	40	190	14	0
2	16 ,, 32 ,,	3 ,, 6 ,,	40	285	21	10
3	18 ,, 36 ,,	4 ,, 0 ,,	40	390	27	0
4	20 ,, 40 ,,	4 ,, 6 ,,	40	570	37	0
5	22 ,, 44 ,,	5 ,, 0 ,,	40	770	47	0

The air, circulating, feed, and bilge pumps are all secured behind the condenser on the port side, and are worked in the usual way with links and levers from the cross-head. Air and circulating pumps are lined with brass, and fitted with brass valve seats, guards, and muntz metal rods, and the feed and bilge pumps have brass plungers, brass valves and seats, all necessary air valves, drain cocks, and air vessels.

Stern tube of cast iron, bush with brass and lignum vitæ. Propeller shaft of steel, lined with brass. Propeller of cast iron, of suitable diameter and pitch. The handles for manipulating engines are arranged on deck, and all of ample length. A suitable gear is arranged on deck for tipping the crank pin off the centre Working pressure, 90 lbs. per square inch.

No.	Diameter of Cylinders.	Stroke.	I.H.P.	Revolutions.	Weight.	
					Tons.	Cwts.
1	5 ins. and 9 ins.	8 ins.	15	230	1	5
2	6 ,, 10½ ,,	10 ,,	26	200	1	15
3	7 ,, 12 ,,	12 ,,	37	180	2	10
4	8 ,, 14 ,,	12 ,,	50	180	3	8
5	9 ,, 16 ,,	14 ,,	68	160	4	10
6	10 ,, 18 ,,	16 ,,	90	150	6	0

SMALL ENGINES ON BOARD SHIPS

Like colliery and mining powers, for fans, pumps, winches, hoists, and other small powers on board a modern steam ship the electric motor should be employed, and, to some extent, is employed both in the navy and in mercantile marine engineering. Steam engines used for these purposes are generally of one or other of the types already described. The windlass and cargo hoist engines are generally designed and built as part of the whole machine. Fig. 79 is an example of this practice in a steam windlass by Clarke, Chapman, & Co. In this figure the engines are vertical, but they may be

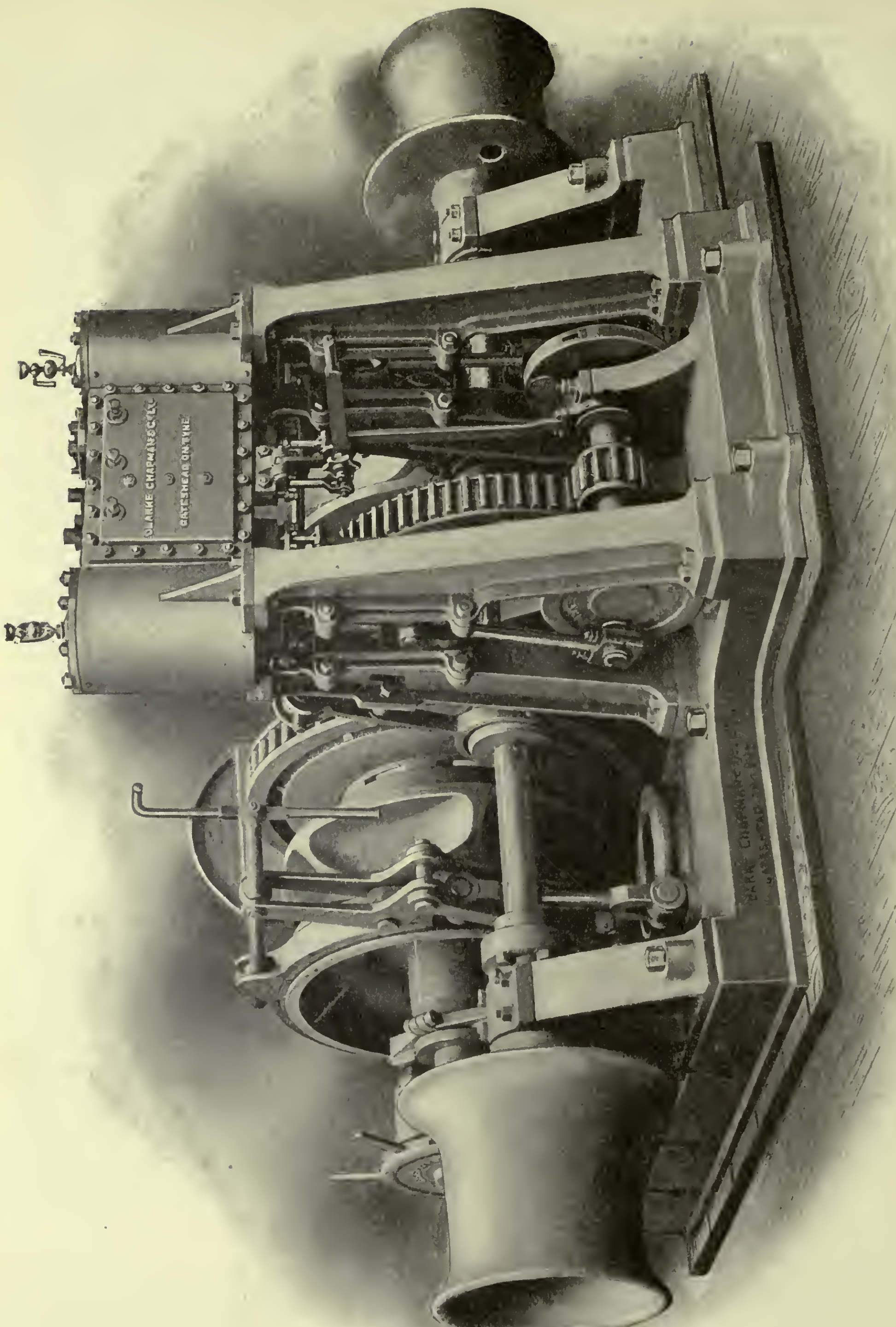
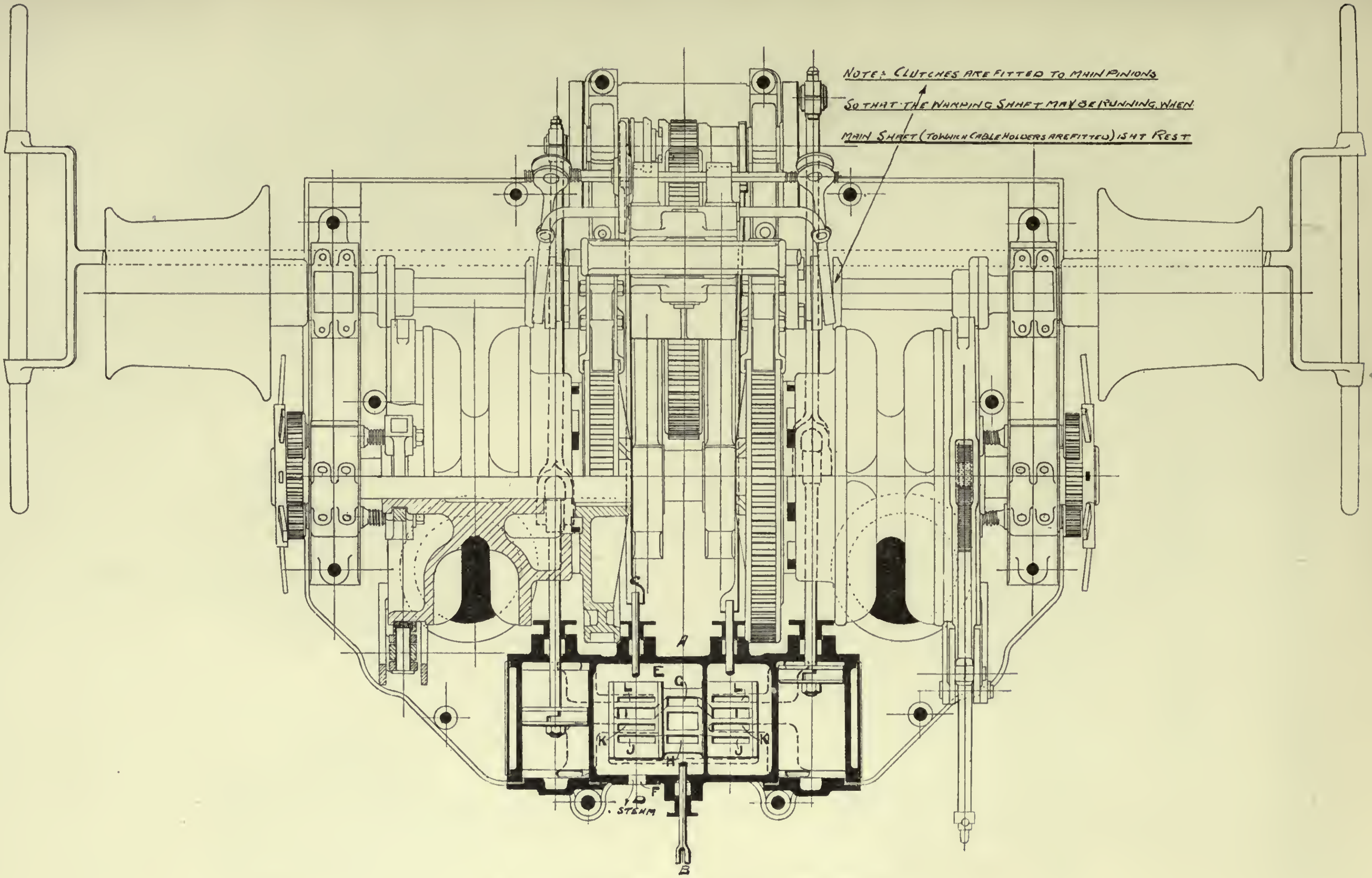

CLARKE CHAPMAN & CO LTD
GATESHEAD-ON-TYNE

FIG. 79.—Vertical Winch Engine.



NOTE: CLUTCHES ARE FITTED TO MAIN PINIONS SO THAT THE WARPING SHAFT MAY BE RUNNING WHEN MAIN SHAFT (TO WHICH CABLE HOLDERS ARE FITTED) IS AT REST

FIG. 80.—Horizontal Winch Engine. Sectional Plan.

horizontal, as shown in Figs. 80 and 81, showing the valves for distributing and controlling the steam, also the small detail drawings of the valves in Figs. 82 and 83.

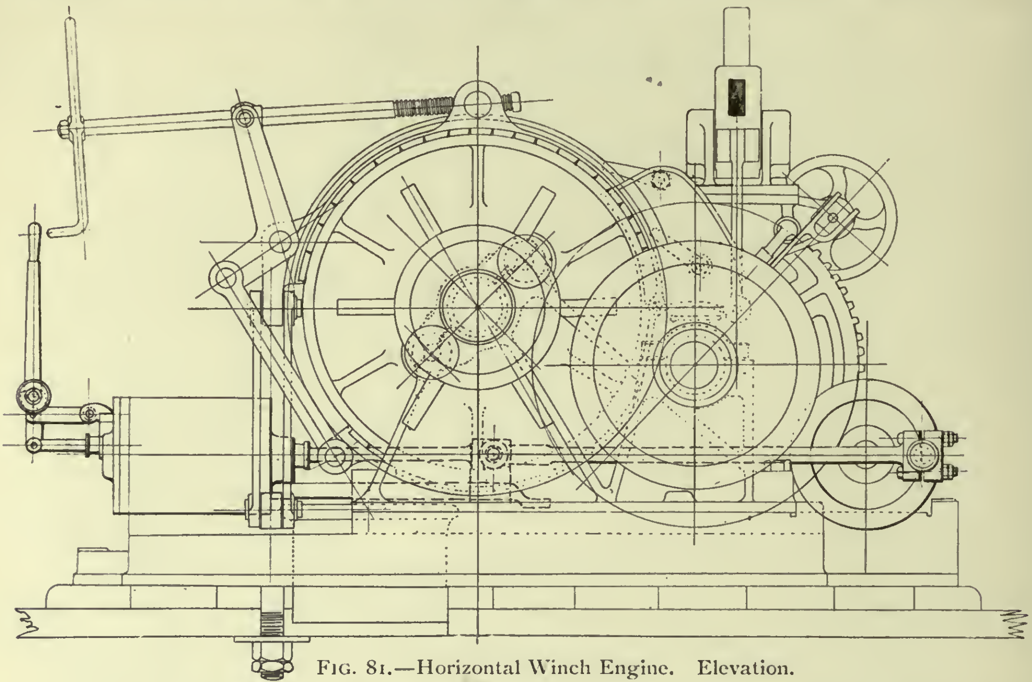


Fig. 81.—Horizontal Winch Engine. Elevation.

In order to understand the action of these valves it is necessary to observe the instructions and motions required.

To start the engines, steam is admitted into the chest E through pipe F (Figs. 80 and 82). The controlling valve is moved from the middle position to admit steam into port G or H (Figs. 80 and 83), according to the direction the engine is required to run. Steam runs from the port G or H into ports I or J; from thence it passes alternately into the ports K and L, and then to the ends of the cylinders.

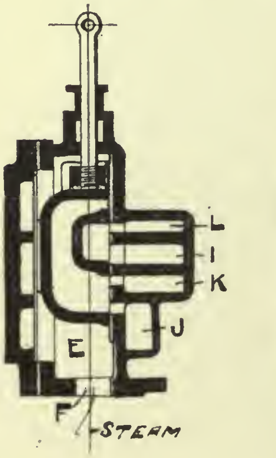


Fig. 82.—Section at C D.

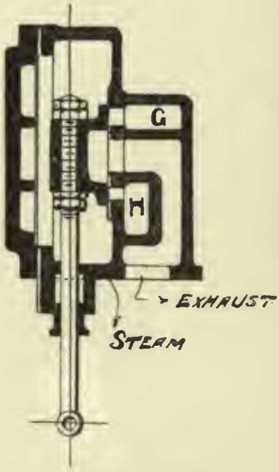


Fig. 83.—Section at A B.

To stop the engines, bring the controlling valve into the middle position, as shown in Fig. 83, thereby shutting off steam to the ports leading to either ends of the cylinders.

To reverse the engines, move the controlling valve over so as to admit steam into the opposite port, namely, if steam has been passing through port H, then shift the valve over to get steam through G, and then the exhaust passes through H away to exhaust pipe.

It will be thus seen that the reversal of the engines is accomplished without any valve gearing other than the controlling valve and hand lever.

These windlasses have considerable interest as machines, being fitted with very ingenious and effective brakes and chain grips, but they do not come under prime movers for consideration.

SINGLE-ACTING SIMPLE ENGINE WITH ROTARY VALVES

Fig. 84 shows a design for a simple steam engine suitable for high speeds, such as required for small boat or motor car propulsion. It consists of a combination of a hollow bar forming a steam chest and having a series of sockets to receive the cylinders, a series of cylinders held in the sockets, the bar having a series of steam spaces communicating with the cylinders, and a valve contained in the hollow bar, whereby the flow of steam to the cylinders is controlled.

The valve is a cylinder with ports cut for exhaust and steam, an inner bar for reversing, stopping, and starting. The valve is driven by bevel gearing, and the regulation effected by a hand lever whereby the bevel wheel can be shifted on the shaft.

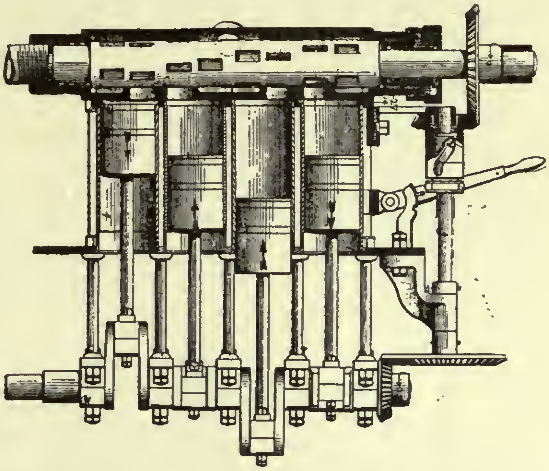


FIG. 84.—Four-Cylinder Engine, with Rotary Valves.

STEAM STEERING ENGINE

This indispensable prime mover on large vessels has taken the place of the hand steering wheel. Before its introduction large vessels in rough weather required as many men as could be put on the wheels to manage the ship. And several wheels were put on the steering shaft, so that six or eight men could be put to the steering. The *Great Eastern* steam ship sometimes required twenty-four men to steer her.

Now the man at the wheel has only to turn a small wheel to move the steam valve of the steering engine. The steering gear does the rest. A valve gear for the purpose is shown in Fig. 85, and is described by the inventors as follows:—

This invention relates to steam steering gear, whose controlling valve is operated by a hunting screw, and whose motion is controlled by the revolutions of the crank shaft. A represents the control valve casing, and B the controlling valve, whose rod C is connected to and operated by the steering wheel and hunting gear. The valve B may be of the piston type, and is so mounted on the valve spindle C as to have a certain amount of play on the said spindle. Connected to the valve B is a supplementary piston F, working in a suitable cylinder G, which is provided with ports and passages *g* in conjunction with the ports and passages *a* of the controlling valve, each to each, and connected by pipes in such a manner that on the controlling valve B reaching any desired

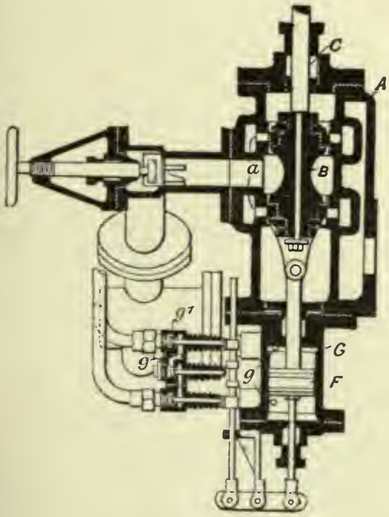


FIG. 85.—Steering Engine.

position of its travel, as in approaching the neutral position, a port *g* in the valve piston and casing is opened to the steam escaping past the controlling valve B, and the corresponding ports *g* and *a* on the exhaust side are connected together, causing the supplementary piston F to move and pull or thrust the controlling valve B over the ports *a* in its casing, and effectually close them, so that the supply of steam to the steering engine is shut off dead. The movement of the piston F actuates a tappet rod, which acts on the stems of the valves g^1 to admit or exhaust steam to either end of the casing G. The closing of the valves g^1 is simultaneous with the opening of the valve g^2 for the purpose of establishing equilibrium between the two sides of the piston F, and thus returning the control valve to its central position.

STEAM STEERING GEAR

The steam steering gear of Messrs. Alley & McLellan, of horizontal pattern, is shown complete in Fig. 86, and in section in Figs. 87, 88, and 90. It consists essentially of a pair of steam engines with cranks at right angles, driving through worm gearing a winch working a chain which operates the helm. The main feature of all steering gears is the steam controlling and distributing valves. The distributing valves are like those on the steam windlass slide valves, and stopped, started, and reversed by a valve in the case of the windlass worked by hand; but in the case of the steam-steering gear this stopping, starting, and reversing valve is operated by an automatic motion attached by shafts and gearing to the little steering wheel worked from the bridge or lookout.

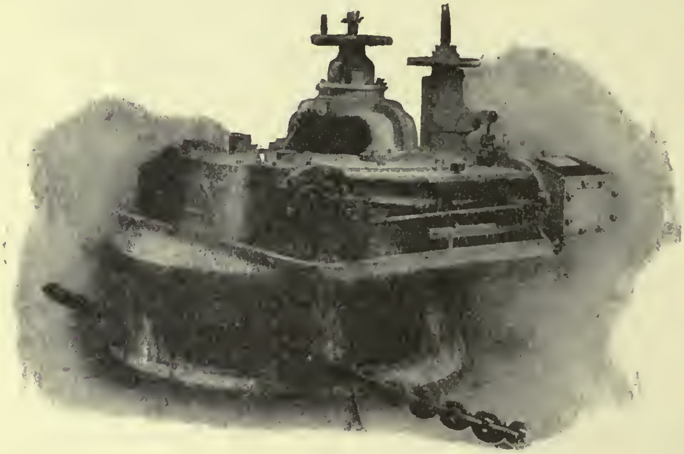


FIG. 86.—Horizontal Steam Steering Gear.

This automatic motion keeps the engines running, and hauling the helm to port or starboard as long as the man at the wheel keeps his little wheel moving for port or starboard; and when the man stops the small wheel the engines stop also at the position the helm may at the moment be desired, so that every movement of the small wheel is duplicated by a similar movement of the chain wheel on the steam-steering gear. The main points, then, in every steering gear are the automatic motion gear in connection with the small steering wheel, and the valve operated on the engine by the automatic motion; for the rest, it is only a windlass. Referring to Fig. 87, sections of the valve and cylinders, and Fig. 88, a section of the valve which is operated by the automatic motion, steam entering steam pipe A passes to controlling valve. When the controlling valve is moved by means of automatic motion in direction M, the steam enters port B and passes to the cylinder slide valves EE. The slide valves EE are constructed with two ports, so that the steam passes through the one into the cylinder and out through the other into port C. From there it exhausts through the controlling valve into exhaust pipe D.

For setting the slide valves, when the cranks are either dead top or bottom, as shown in Fig. 89, the cylinder valves should be in the position shown.

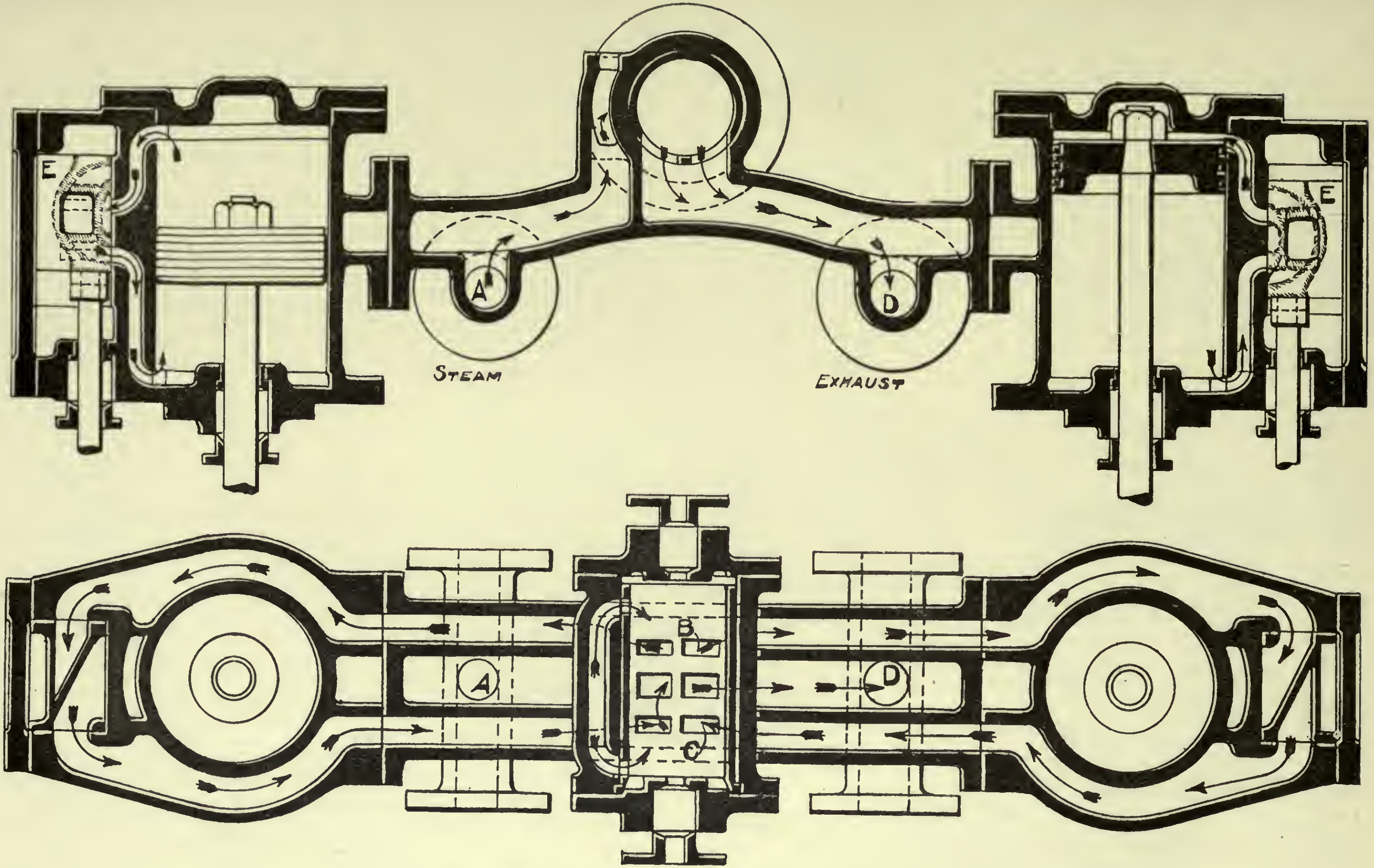

E
A
STEAM
EXHAUST
D
E
A
B
C
D

FIG. 87.—Longitudinal and Transverse Sections through Cylinders and Valves.

When the steering wheel is reversed by the operator it reverses the controlling valve and sends it in direction N (Fig. 88), uncovering port C to steam and port B to exhaust, thus reversing the motion of the gear, as shown in Fig. 87.

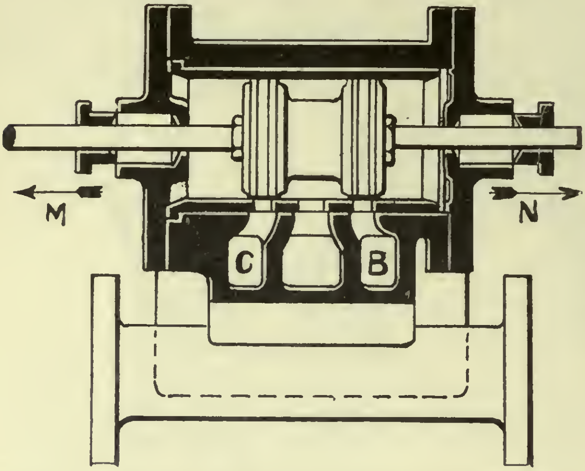


Fig. 88.—Longitudinal Section through Controlling Valve.

The automatic motion is shown in Fig. 90, in the sectional elevation. The controlling valve P is shown connected to a lever L—by which it can be lifted or depressed so as to reverse the engine. So long as the small wheel is rotated by the steersman the valve is held open one side or the other, but immediately the small wheel stops the valve is pulled into and held in the mid position, closing ports C and B and stopping the engine.

The general arrangement of the machine may be gathered from the elevation and plan shown in Fig. 90. Between these two views a drawing of the connecting and piston rods is shown.

Referring to the sectional view, the spindle R with the screw thread T works in a screwed sleeve Q, which carries a pinion wheel V gearing into the large worm wheel X; the spindle R is turned by the small steering wheel. When the spindle is turned the screw T moves up or down in the screwed sleeve Q of the pinion wheel V, and by means of the lever L opens the valve P and starts the engine; and as long as the steersman keeps the small steering wheel moving the engine runs on, for the sleeve Q (which forms the nut for the screw spindle) and the screw spindle R move round together, the spindle being turned by the steering wheel and the nut Q by the pinion V, so that the nut Q and screw T turn bodily together, and the valve P is held open; but immediately the steering wheel stops the screw spindle R stops and the nut Q going on screws the spindle R up or down, and so closes the valve P and stops the engine. The pinion V is called the hunting pinion.

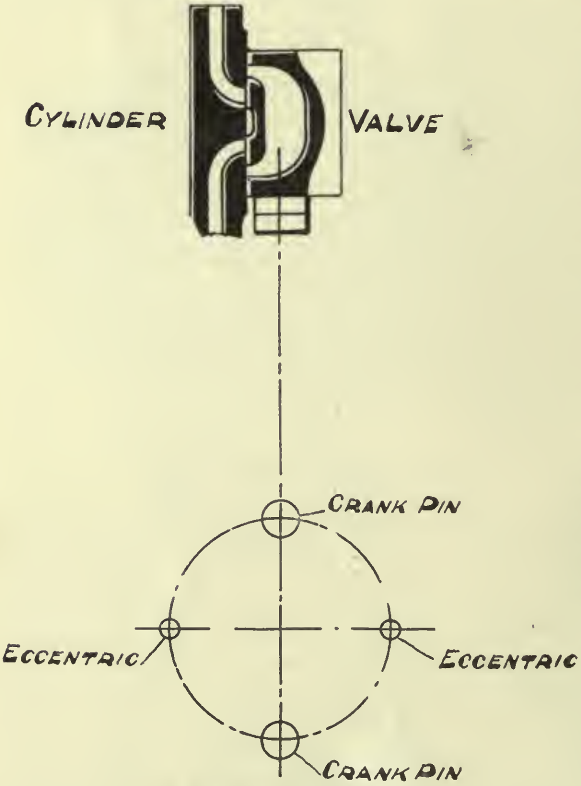


Fig. 89.—Positions of Valve and Crank.

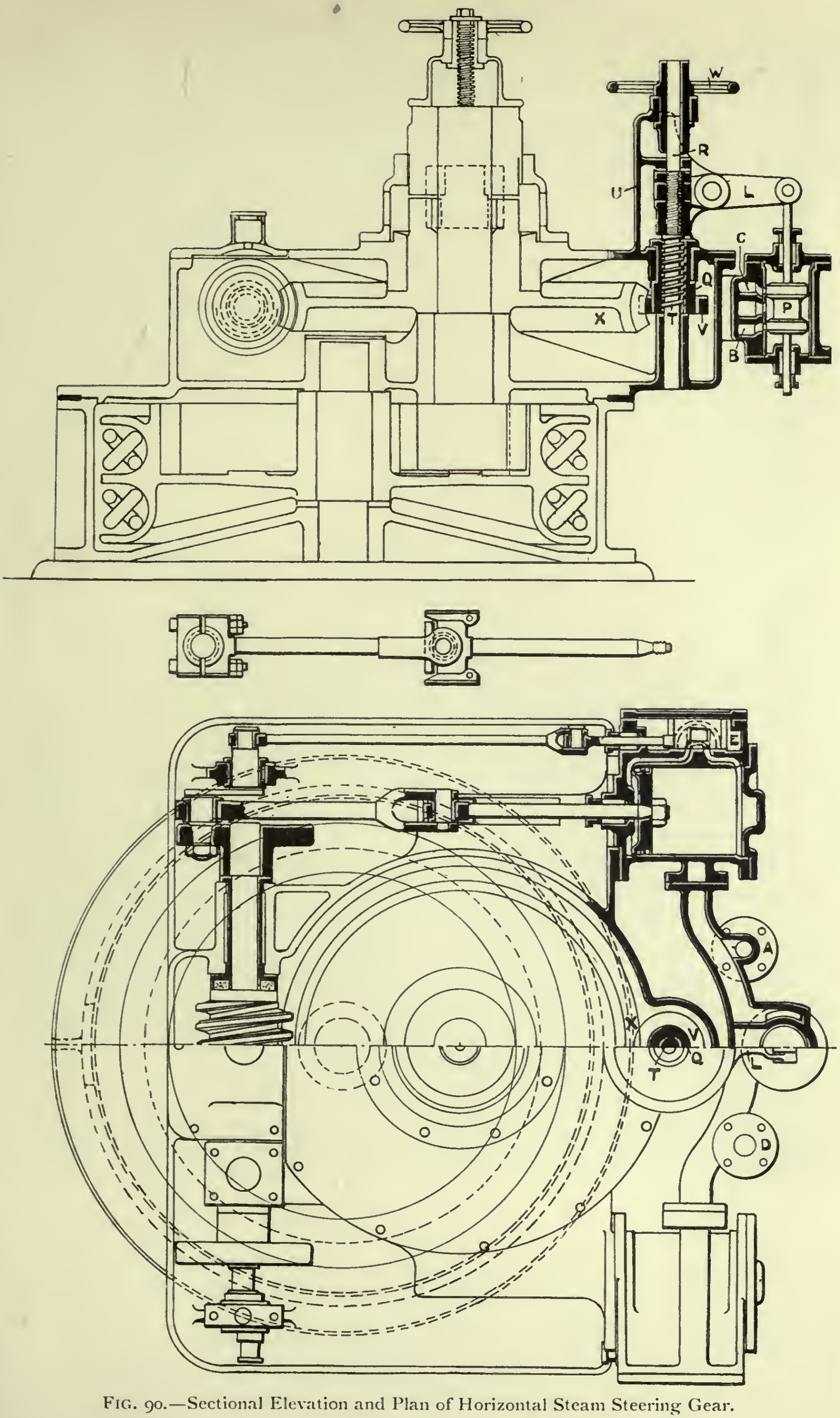

W
R
U
L
C
Q
P
X
T
V
B
E
A
X
V
T
Q
L
D

FIG. 90.—Sectional Elevation and Plan of Horizontal Steam Steering Gear.

STERN WHEEL VESSELS

Fig. 91 illustrates the double wheel with engine drive between, as made by Messrs. Alley & M'Lellan. They are specially useful for high speed, light draught, and good manœuvring, and are on the whole exceedingly simple; the machinery being all on deck, is readily accessible.

For exploring purposes, or for the navigation of rapids or narrow rivers, stern wheelers have peculiar advantages. The greatest of these are the extreme simplicity of the slow-moving machinery, the way in which the wheel is protected by the hull, and the extremely light draught it is possible to give them. Another remarkable fact known to those who have worked them is, that in consequence, perhaps, of the position of the wheel being on the top of the following wave when ascending a rapid or going against a strong current, the vessel is enabled to make more headway than a side wheeler possessed of the same speed in smooth waters. Again, if a stern wheeler runs on a sandbank, if the engines be reversed a stream of water is sent on to the rudders, and a

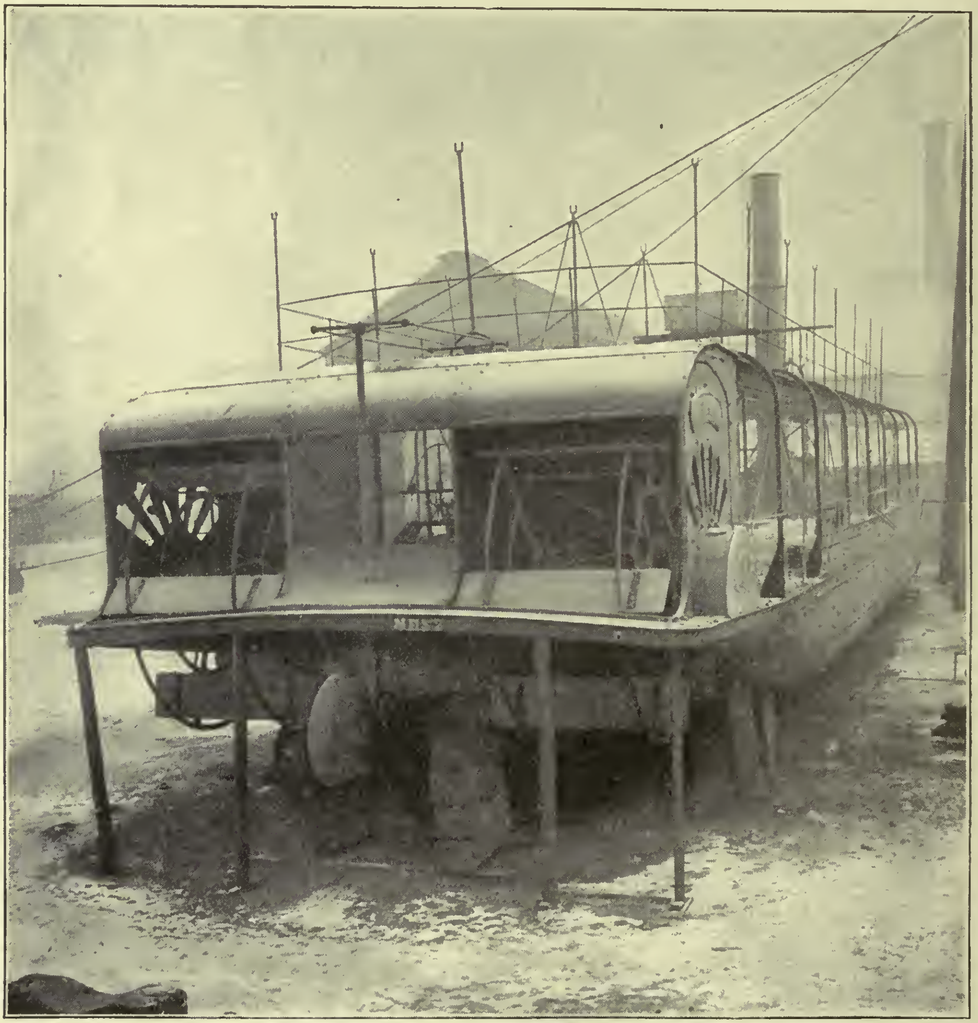


Fig. 91.—Double Stern Wheel Steamer.

steering impulse given, under which the stern can be moved from side to side, and the boat will, in most cases, be able to wriggle off easily. Stern-wheel steamers are better for service in out-of-the-way places than side wheelers, because of the smaller breadth occupied and the greater strength of the hull, and better than screw steamers, because of the lighter draught they can work in, and the fact that all the machinery is easily got at without the necessity of docking the boat or lifting her stern out of the water.

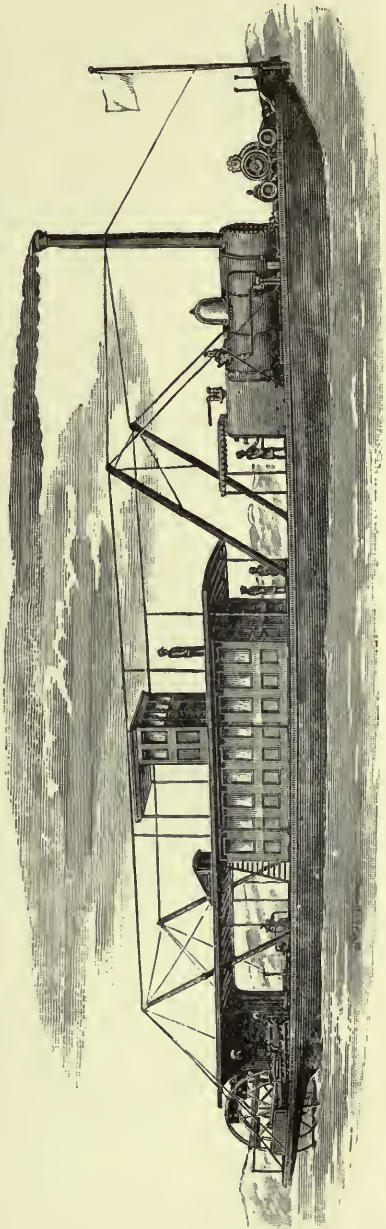


Fig. 92.—Stern Wheel Steamer. Draught, 15 inches loaded.

The engines and boilers of these boats being at the extremities (seen in Fig. 92), their weight can be readily distributed over the hull by means of struts and bracing; but when extreme lightness of hull is wanted, kingposts and bracings are fitted.

Fig. 93 illustrates a set of compound surface condensing engines for a paddle steamer, with cylinder 16 and 32 inches diameter by 36 inches stroke; with 120 lbs. pressure, at 40 revolutions per minute, they indicate 200 horse-power. The valve gear is the ordinary Stephenson's link motion, but Joy's gear has been successfully employed on this type of engine.

The condenser forms a convenient footstool under the main bearings, and is cylindrical. The brackets supporting the main shaft are of cast steel, while the air feed and circulating pumps are driven off a bell crank worked from the high-pressure cross-head. The illustration (Fig. 93) clearly shows the convenient "get-at-ability" of the whole engine. In this case two sets of engines were fitted in one steamer, each driving one paddle wheel.

Fig. 94 shows another paddle engine of very much the same design, but jet condensing, and on this account, there being no condenser below the shaft, the engine is in a more horizontal position. This particular engine was of 600 indicated horse-power, with cylinders 20 and 40 inches diameter × 48 inches stroke, running at 50 revolutions per minute, motion hand reversing gear. It is a very open and accessible design.

The surface condensing type is, of course, necessary for vessels working in salt water or dirty water, in order to save the clean condensed water for the boilers.

In fresh clean rivers and lakes the jet condenser, being simpler and less bulky, is preferable; and as may readily be seen in comparing the two types in Figs. 93 and 94, the whole engine is more compact and low-lying with the jet condenser.

The stern-wheeler and side-wheeler paddle boat is mostly used for light draught, with a load which does not vary greatly. We have seen that Thornycroft, by means of the screw turbine type of propeller, has adapted the screw to shallow draughts; Messrs. Yarrow & Co. have also a plan for working a screw in shallow draughts in a tunnel vessel.

In the year 1875 Messrs. Thornycroft constructed a very successful twin-screw launch on the tunnel system for Sir John Fowler, for the navigation of the Nile. Her dimensions were 63 feet in length by 8 feet 6 inches beam, 2 feet 6 inches draught.

Coming to the latest development of this type of vessel, the upper part of the tunnel is considerably above the water line, thus enabling the diameter of the propeller to be greater than the draught of water. For example, in a boat drawing a foot, propellers of 2½ feet diameter, and in a vessel drawing 2 feet, propellers of 4½ feet to 5 feet diameter. When the vessel is at rest the water level inside the tunnel is naturally the same as it is on the outside; but when the propeller begins to revolve, the air which is enclosed in the upper part of the tunnel is forced out and replaced by solid water. By this means it

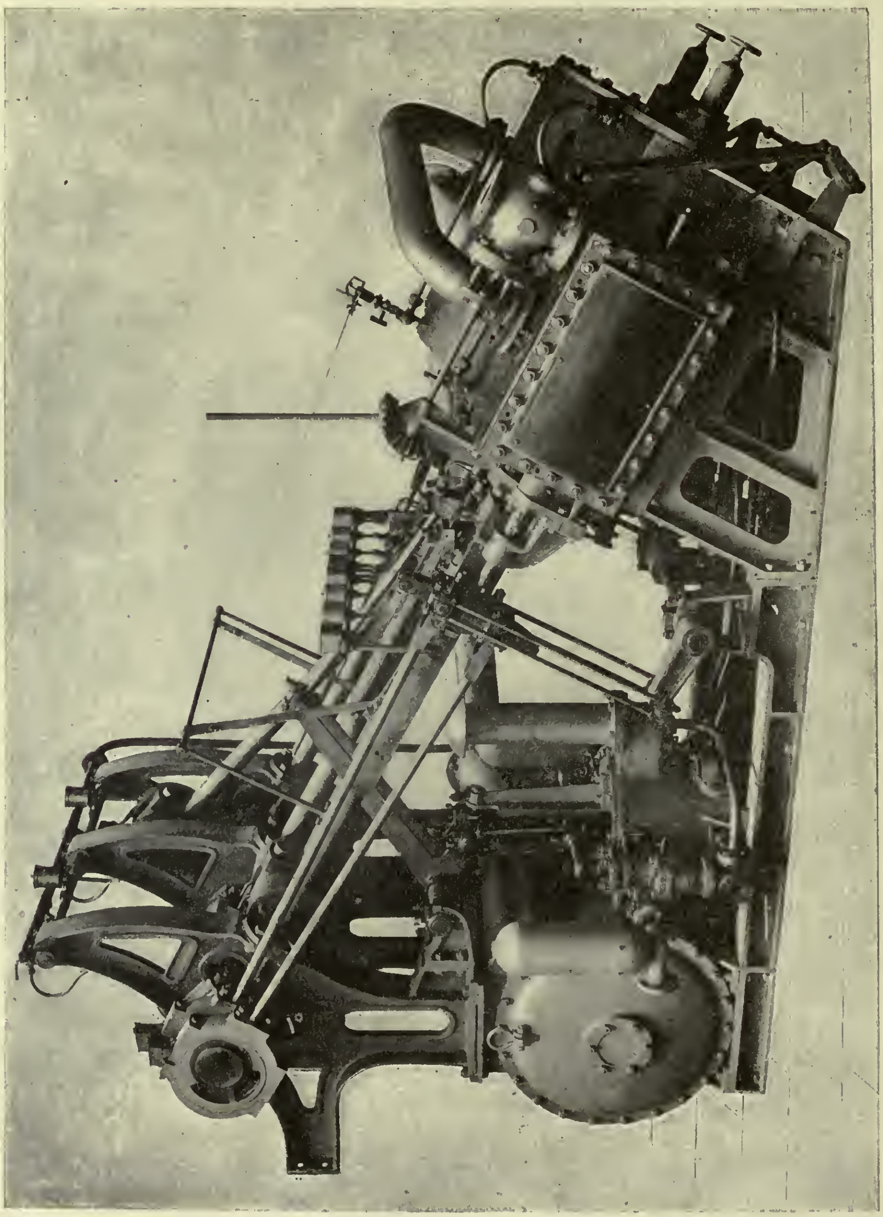


FIG. 93.—Compound Diagonal Paddle Engine. Surface Condensing.

will be seen that a large propeller, capable of utilising considerable power, can be used in combination with a shallow draught. There will be an increased resistance to the forward motion of the vessel, due to the action of the screw in reducing the pressure of water at the inclined part of the tunnel forward of the propeller, and this increased resistance is common, more or less, to all screw ships, but it is probably proportionately greater in this class of vessel than in those where the propeller is in the usual position.

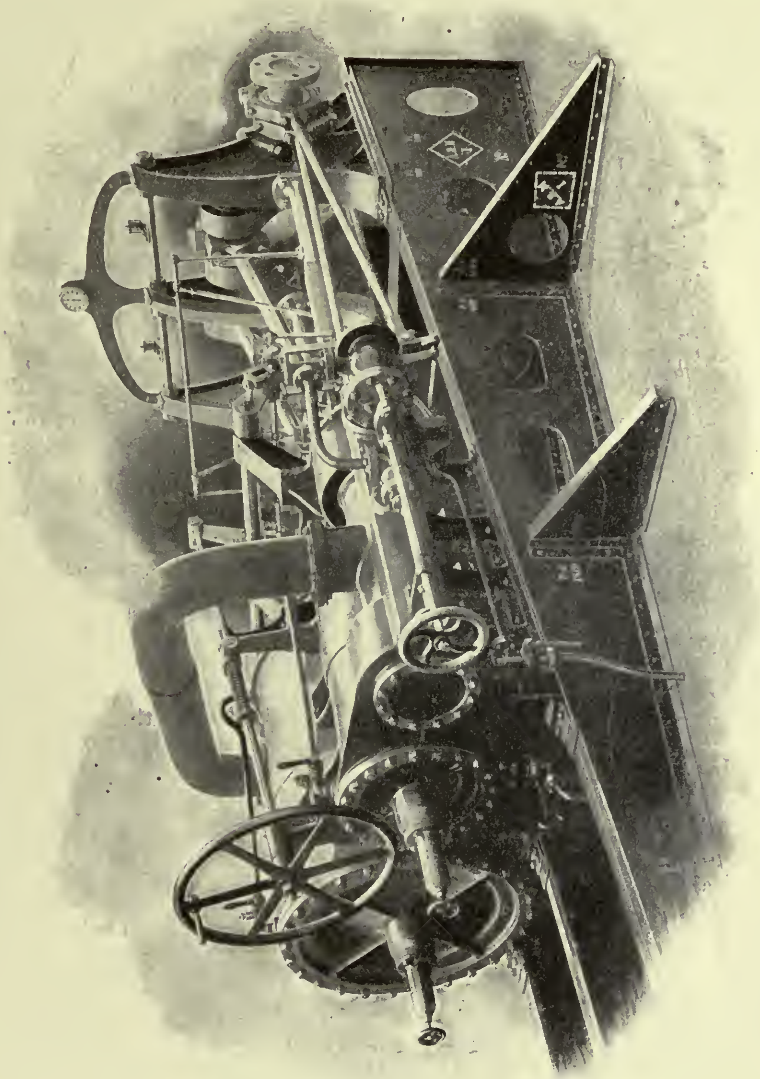


FIG. 94.—Compound Diagonal Paddle Engine. Jet Condensing.

There is also a loss of efficiency due to the resistance of the inclined surface of the tunnel aft of the propeller.

The inclined portion of the tunnel aft of the screw should be as nearily horizontal as possible, so as to diminish this resistance; but this would increase the length of the tunnel and involve greater draught, because to augment the capacity of the tunnel below the water line is just so much loss of displacement, and the water in the tunnel above the water line is equivalent to just so much load carried when the boat is at rest and the tunnel full. It is therefore desirable to reduce the capacity of the tunnel to a minimum, as considerations of draught render it not always practicable to select a favourable inclination at the after part of the tunnel without causing losses, such as those alluded to above, which may be even greater than if a steeper inclination of tunnel be adopted. The tunnel is sealed on all sides, this being necessary because, when once the air is forced out, it must never be allowed to pass in, or the propeller would not be working in solid water. As regards the forward part and the sides, there is no difficulty in sealing the tunnel satisfactorily, but the extreme after part of the tunnel should be arranged to come two or three inches below the water line, *i.e.* sufficiently below the surface to exclude the air. The action of expelling the air is almost instantaneous. The air is driven out of the tunnel, and the propeller then works in solid water.

In these tunnel vessels the screw is accessible by a door in the highest part of the tunnel, and a new propeller can be readily fitted while the vessel is afloat.

Messrs. Yarrows' improvements on the tunnel consist in making the after inclined roof of the tunnel hinged as a flap, so that the tunnel may be closed with the flap under the water line at starting

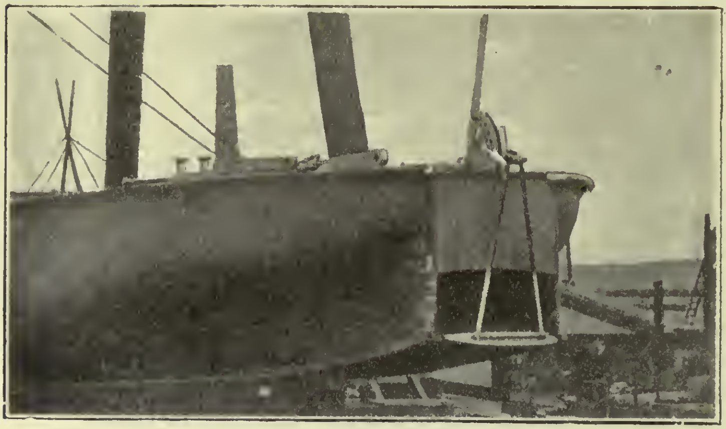


FIG. 95.—Position of Flap for Light Draught.

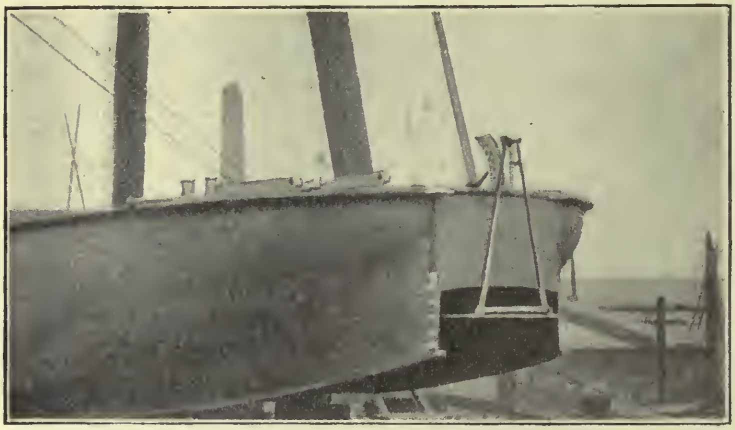


FIG. 96.—Position for Intermediate Draught.

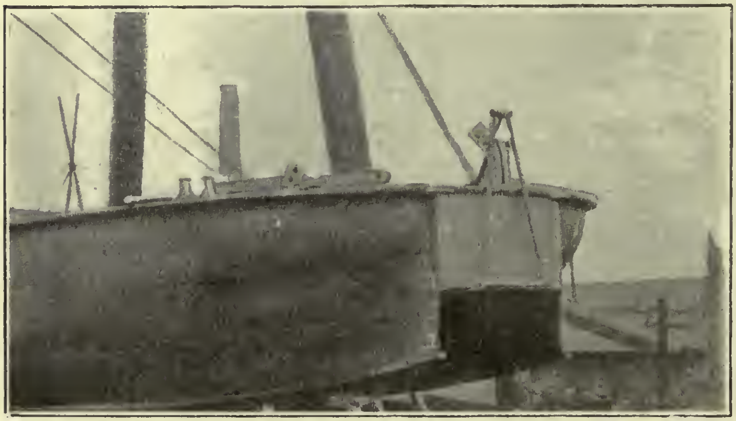


FIG. 97.—Position for Maximum Draught.

in order to exclude the air. It has been found that after the boat is under way the after extremity of the tunnel may be above the water line by 6 or 8 inches, the flow of water preventing the air from entering, at the same time improving the result, due to reduced resistance of the inclined surface. It has been shown that the after part of the tunnel should be below the water line when the vessel is starting light; but if it were fixed in that position it would be unnecessarily low down when the vessel is loaded, thereby involving greater resistance than if the after part of the tunnel terminated at a level sufficient for the loaded boat.

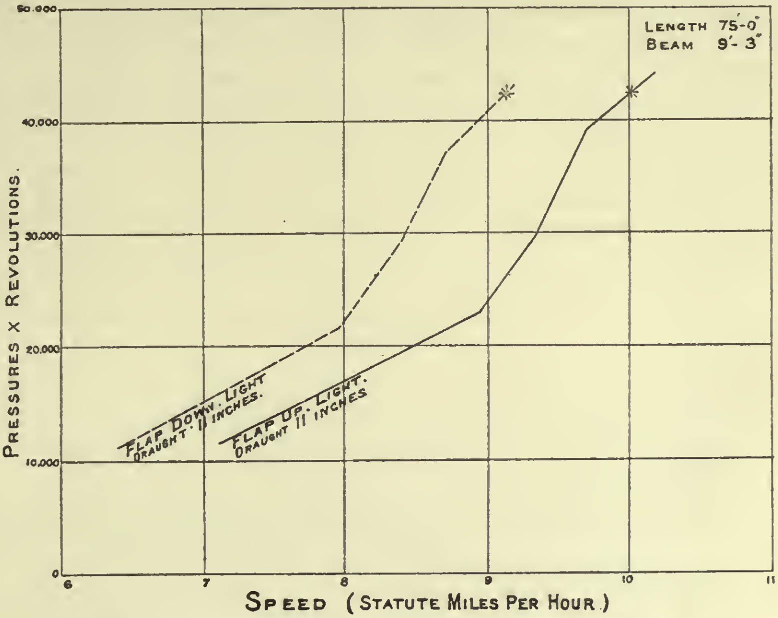


FIG. 98.—Shallow Draught Launch. "Yarrow" System.

In more recent vessels of this kind the upper part of the tunnel, from the propeller to the stern, is hinged in such a way that it can be raised and lowered to any desired height, either by mechanical means or automatically. Figs. 101 and 102, and the three views, Figs. 95, 96, and 97, of the stern, fully explain the system. Fig. 95 represents the hinged top lowered to a position suitable for light draught; Fig. 96 shows it partly raised suitable for an intermediate draught, and Fig. 97 represents it at a height suitable for the maximum draught. Fig. 102 shows the position of the hinged top, or flap, when the boat is light, drawing 11 inches; and Fig. 101, when the boat is loaded, drawing 28 inches. It will be seen at a glance that when loaded, if the after extremity of the tunnel were in the same position as it is when light,

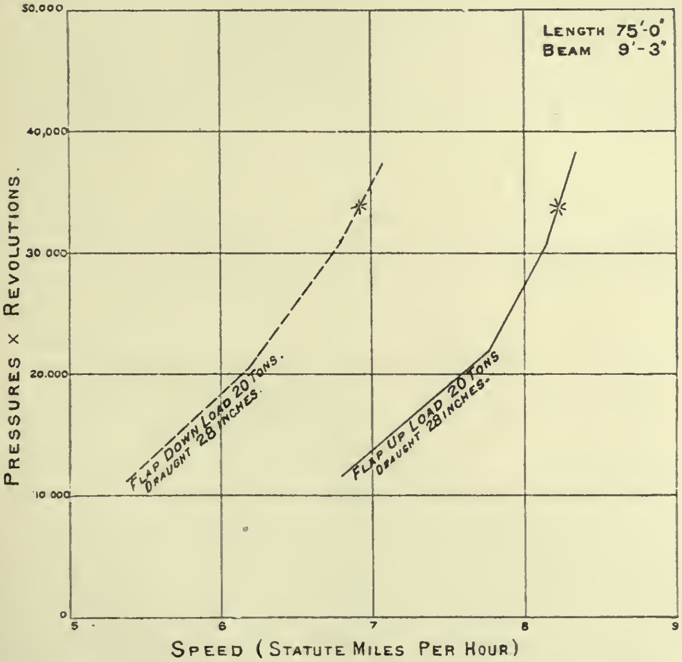


FIG. 99.—Shallow Draught Launch. "Yarrow" System.

it would involve a greatly increased resistance, while by raising the top of the tunnel the water has a clear passage open to it to freely pass away in an opposite direction to that in which the vessel is travelling. The gain by the raising and lowering of this flap is illustrated by diagrams in Figs. 98 and 99. When the launch is light, drawing 11 inches with the same power, the speed is increased from 9.2 miles an hour with the flap down to 10 miles an hour with the flap up; and when the draught is 28 inches, loaded with 20 tons, the speed is increased from 6.9 miles an hour with the flap down to 8.25 miles an hour with flap up, the power at both speeds being the same. As might naturally be expected, the increase of efficiency due to the lifting of the flap is greater when the boat is loaded, the lower speed in both cases being what they would have been if there had been no adjustable flap, clearly showing the advantage of the flap.

Fig. 100 shows one of these launches, 75 feet long by 9 feet 3 inches beam, of which we have built several, and it will be seen exactly what the speed is with the same power with the flap up or the flap down at different draughts. The views in Figs. 101 and 102 show the flap in the lowest and highest positions.

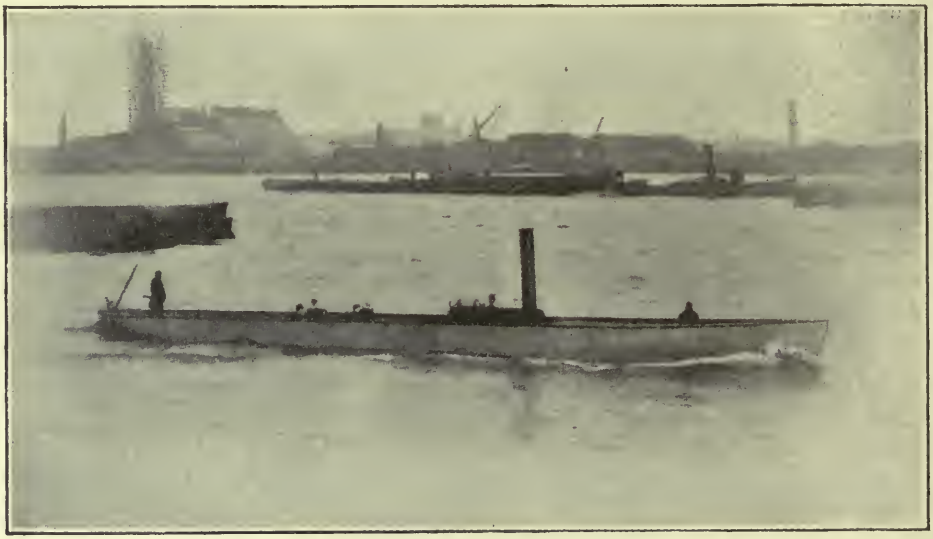


Fig. 100.—Shallow Draught Flap Launch.

This launch gave the following results on trial:—

	Draught.	Stat. Miles per Hour. Flap Down.	Stat. Miles per Hour. Flap Up.
With steam up . . .	11 inches	9.2	10.0
With 10 tons load . . .	20 ,,	7.7	9.0
With 20 tons load . . .	28 ,,	6.9	8.25

COMPARISONS BETWEEN THE PROPELLERS.

The paddle is adopted for shallow draught because it is all outside of the vessel; but it has the disadvantages of great exposure to damages, and varying dip at various loads. At light loads it does not dip into the water deep enough; at heavy loads it dips too much. The Thornycroft and Yarrow shallow draught screws are both well protected from damages, and work pretty well under considerable variations in draught. The screws have also the advantage of running at much higher revolutions than the paddle, so that smaller engines are required. In both cases reversing to go astern is not so efficient as the paddle. The Yarrow flap only works when going ahead.

An excellent comparison was made between a Yarrow tunnel screw boat and a side wheeler. This latter vessel had feathering float side wheels. Her length, draught, and power made her a fair comparison with the screw tunnel boat.

The test was made by towing a set of barges on the same river course, first with one vessel and then with the other, indicating the engines, and by means of a dynamometer measuring the tow rope pull. The total weight of barges hauled was 247 tons.

These results are given in the table on page 80.

From these experiments and other data it was found that the proportion of the power of the engine utilised in towing is very nearly the same in both cases. The paddle boat is superior to the screw at low speeds, and the screw better than the paddle at high speeds. On the average there does not appear to be any appreciable difference. It must, however, be borne in mind that one boat conforms to conditions of draught and dimensions which the other boat does not, the over-all dimensions and draught of the *Little John* enabling her to pass through locks and over shallows which the *Robin Hood* could not.

In considering the question of towing on canals or shallow rivers it is not unreasonable to assume that the screw working in a tunnel damages the banks to a minimum extent, and in this respect is better than the paddle or even a screw in its usual location; because, with the propeller working in a tunnel, the rush of water being in an inclined direction towards the bottom, rather tends to scour it

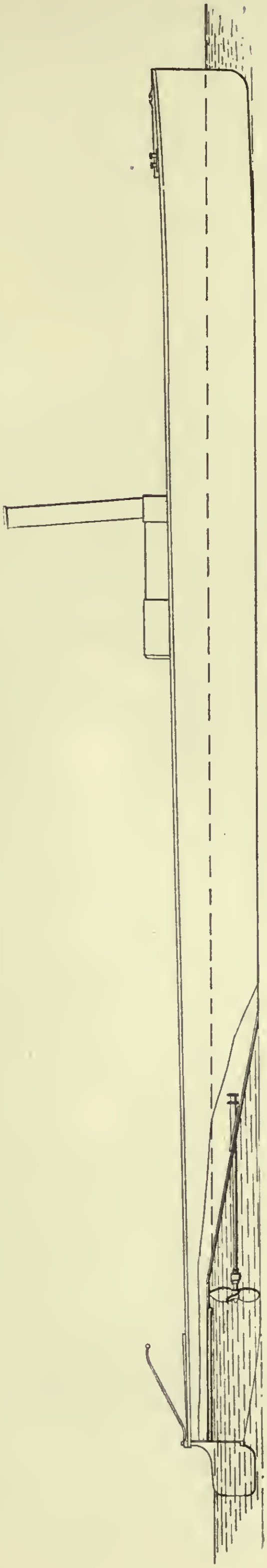


FIG. 101.—Position of Flap when Launch is loaded to a Draught of 28 inches.

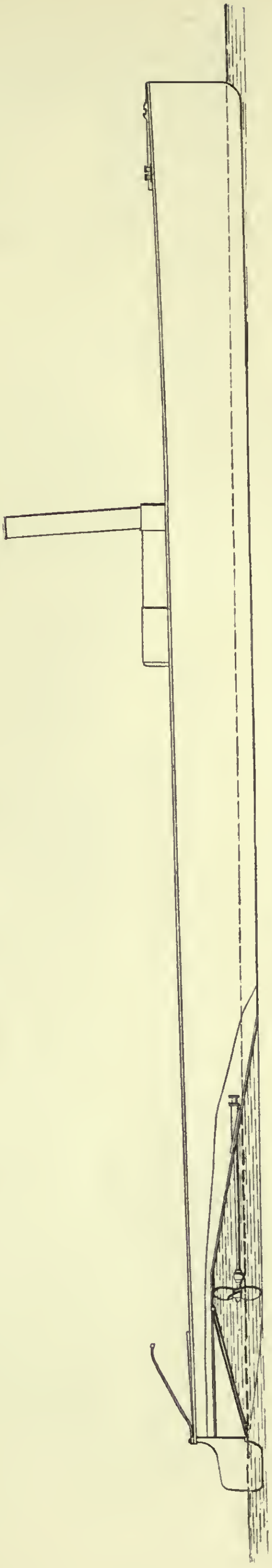


FIG. 102.—Position of Flap when Launch is at its lightest Draught of 11 inches.

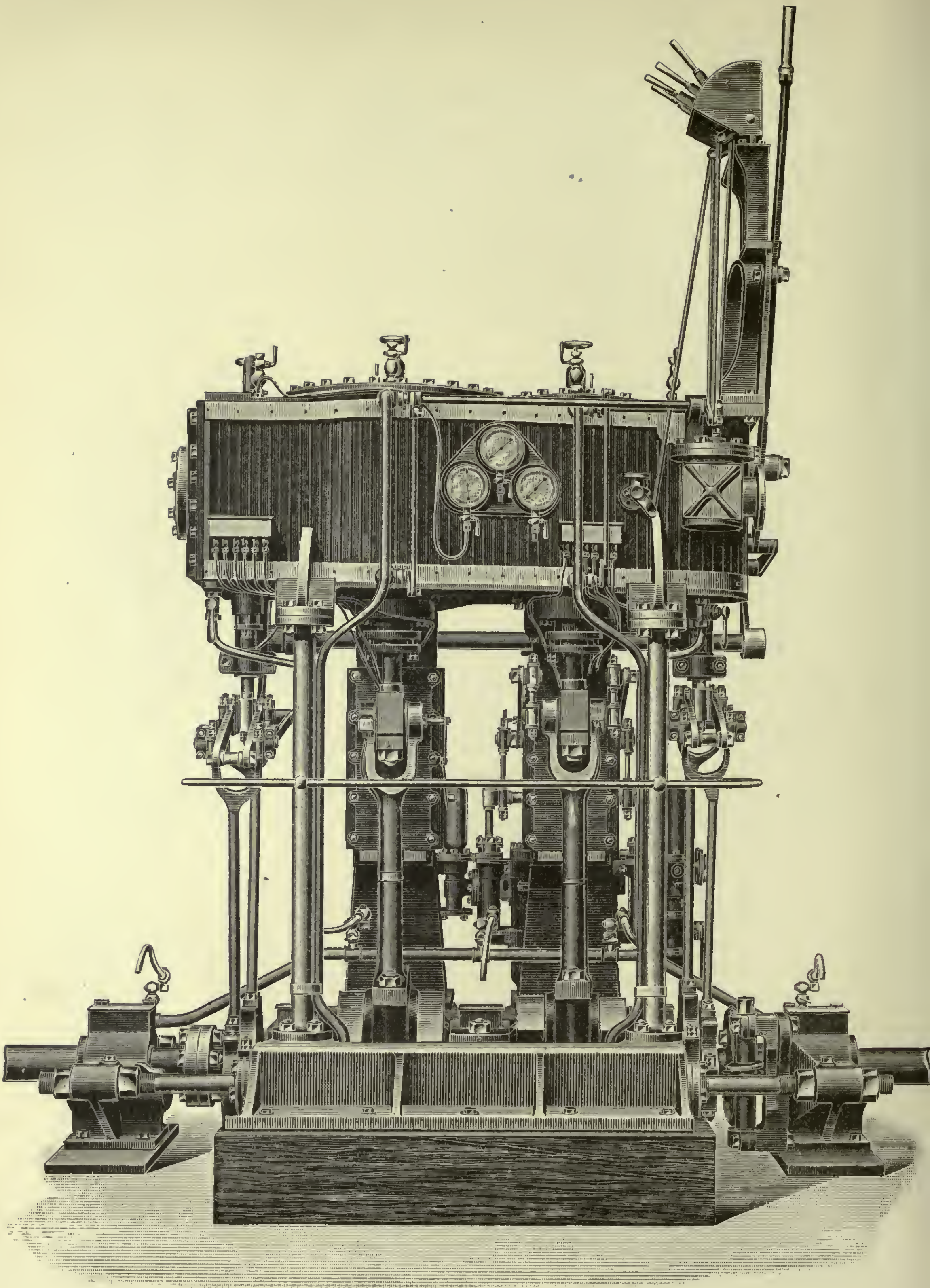


FIG. 103.—Compound Marine Steam Engine (Mumford & Co.).

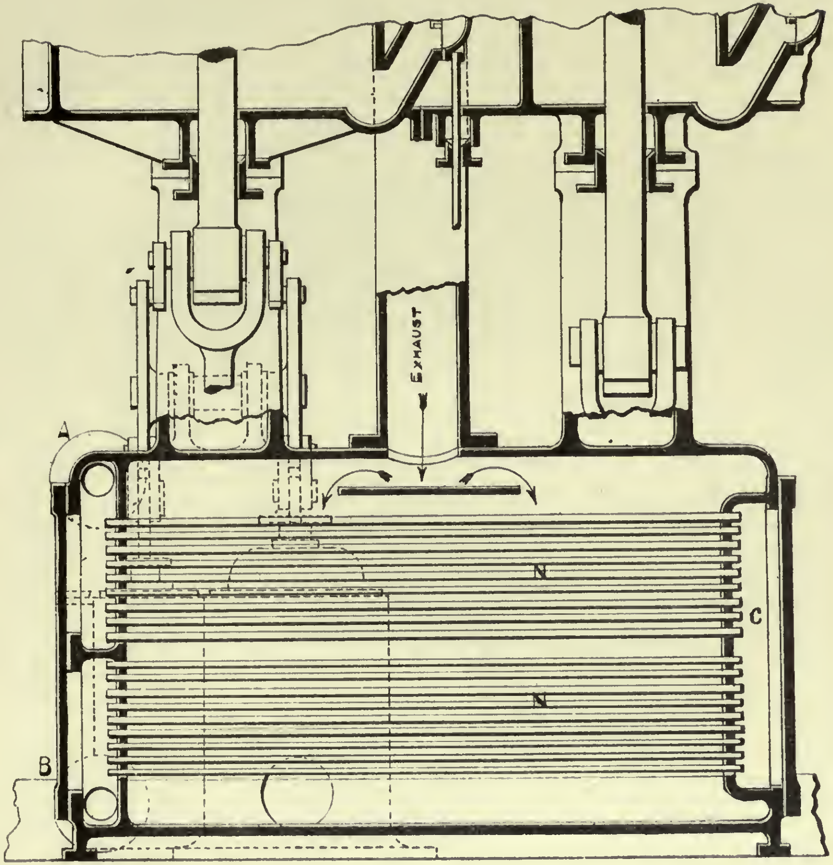

A
EXHAUST
N
C
N
B

FIG. 104.—Sectional Elevation of Marine Engine Condenser.

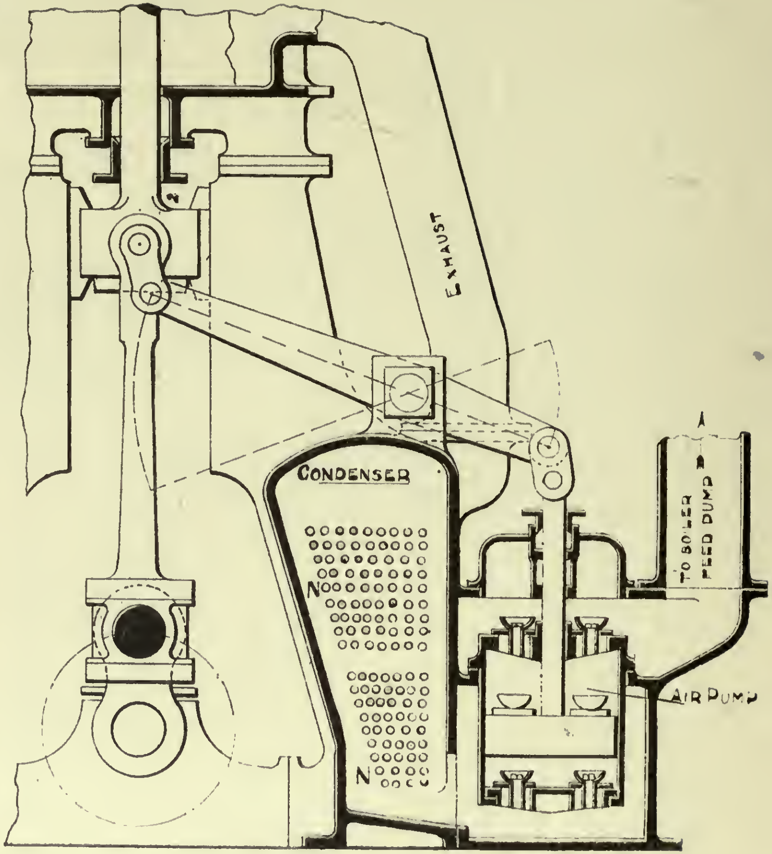

2
EXHAUST
CONDENSER
A
TO BOILER FEED DUMP
N
AIR PUMP
N

FIG. 105.—Sectional End View of Condenser and Pump.

and to keep open the course, while with paddles the effect would be rather to disturb the banks and to cause the earth that is washed away from the sides to settle in the middle.

Now, if we compare the paddle and screw with the jet propeller, it is at once seen that it has all the advantages of both, without any of their drawbacks.

There is no danger of damage to this jet propeller. It works equally well at all depths of immersion—in fact, better when discharged above the water line. The machinery may be placed anywhere most desirable in the boat, and engines of any type or speed employed. There is no difficulty about going astern or manœuvring the boat, and with a properly designed pump and jets is equally efficient to the paddle or screw propeller.

TOWING EXPERIMENTS WITH TUGS *ROBIN HOOD* AND *LITTLE JOHN*.

WITH A VIEW TO TEST THE RELATIVE EFFICIENCIES OF THE TWO SYSTEMS OF PROPULSION.

Name of Tug.	I.H.P. of Engines.	Pull on Tow Rope. Lbs.	Horse-Power at Rope.	Percentage of Power of Machinery utilised in Towing.	Speed (Miles) per Hour.
Robin Hood . . .	90.2	2314	31.6	35.0	5.12
	49.98	1741	20.0	40.0	4.31
Little John . . .	118.24	2901	44.1	37.3	5.70
	94.37	2321	32.3	34.2	5.22
	61.97	1823	21.3	34.4	4.38

SCREW STEAMERS

By far the largest class of marine engines at present is the vertical inverted cylinder engine, with ordinary submerged screw propellers.

The general design of third class is but little departed from in all its varieties. They are made simple high-pressure, compound, triple compound, and quadruple compound.

The simple high-pressure engine is only used very rarely for small boats, and may be of any of the types of vertical high-speed engines already described. The great economy of compounding and condensing is, however, so easily carried out in boats that even in very small units the compound condensing engine is universally used.

In the complete illustration (Fig. 103) no condenser is shown, this engine being constructed for working with a separate condenser. For instance, in a fresh water lake a Körting jet condenser requiring no air pump would be used. The controlling levers are directly above the engine, so that they project through the deck of the boat from which the engine is controlled.

In most compound engines the condenser is a surface condenser built into the engine, and with a self-contained air pump. These are shown in the part sections, Figs. 104 and 105.

Referring to Fig. 104, the condenser casing is of cast iron and forms part of the

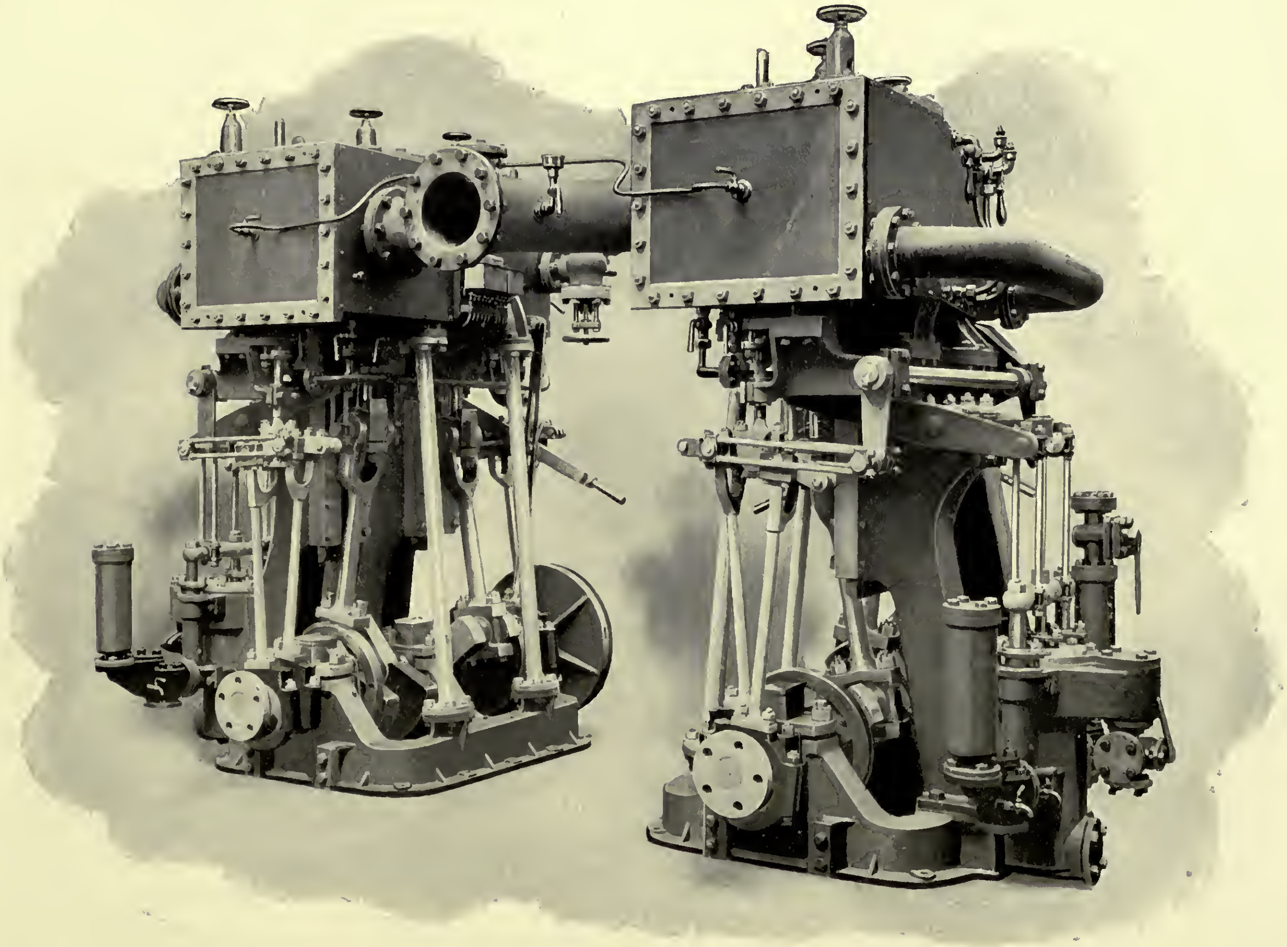


PLATE III.—SET OF TWIN-SCREW MARINE ENGINES.
(ALLEY & MACLELLAN.)

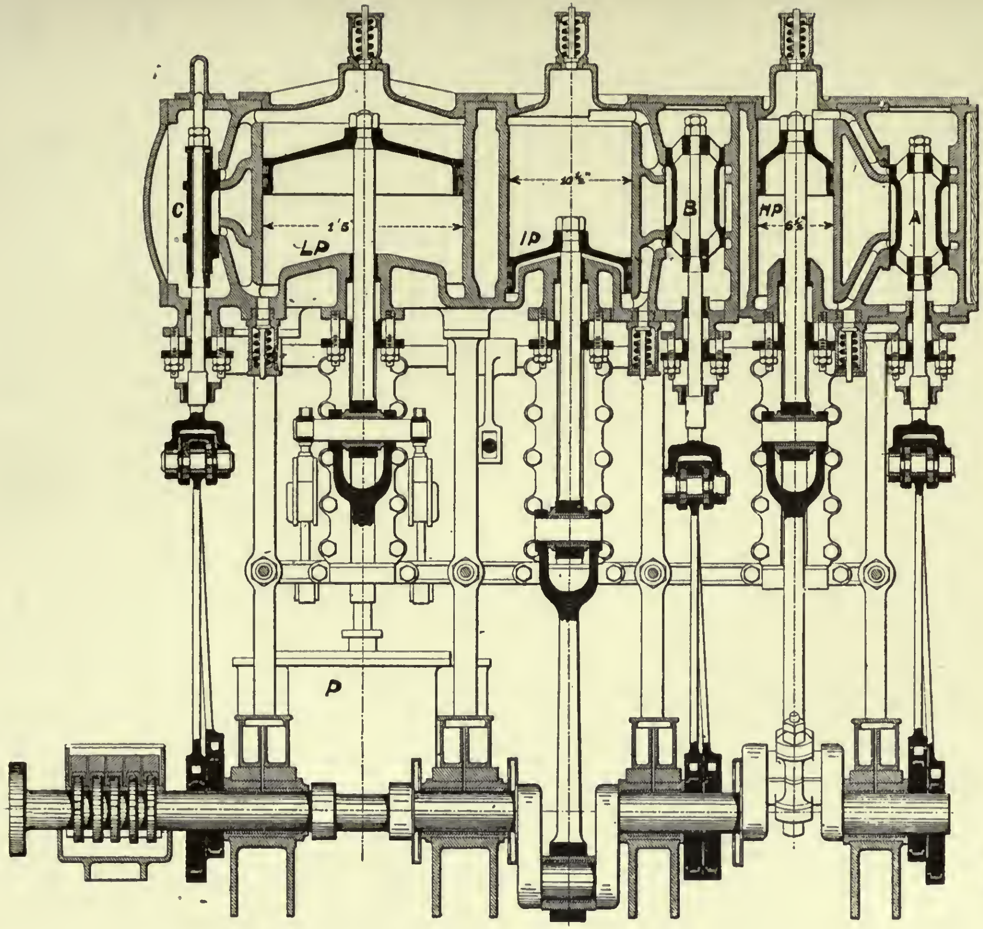

C
1' 5"
LP
10½"
IP
B
HP
6½"
A
P

FIG. 106.—Triple-Expansion Marine Engine. Longitudinal Section.

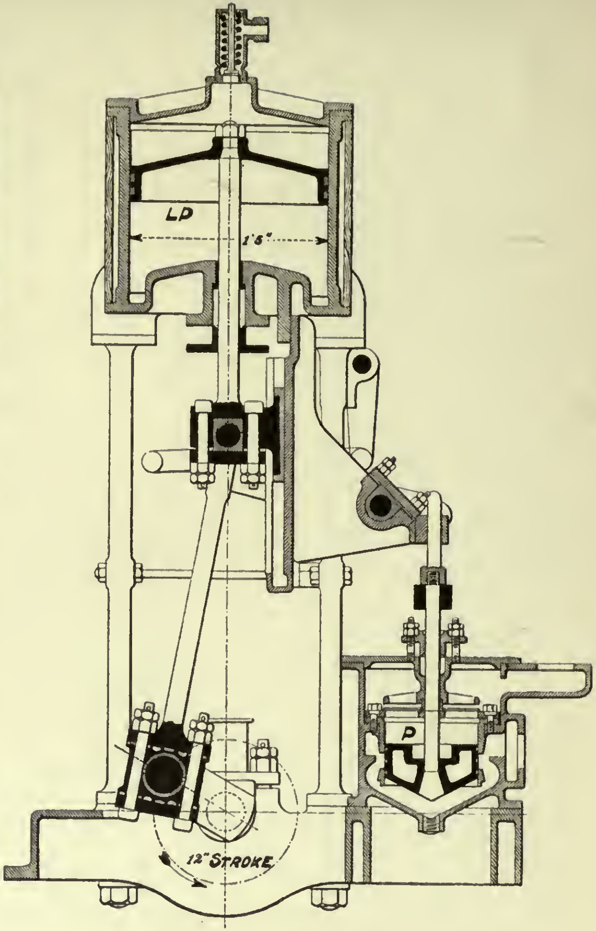

LP
1' 5"
P
12" STROKE

FIG. 107.—Triple-Expansion Marine Engine.
Transverse Section through Low-Pressure Cylinder.

engine frame, and the air pump is also built together with the condenser, as shown in Fig. 105. The exhaust enters at the mid length, and, striking a baffle plate, is spread out over the thin brass tubes NN. The brass tubes are kept cool by circulating water entering at one end A and leaving at the other end C of the upper rows, flowing back by the lower group and out at B.

The condenser here shown has a cast-iron tube plate at each end, into which the tubes are expanded, but it is better practice to make the tube plates of brass, in order that the plates and tubes may expand alike and keep the joints tight.

The simple triple-expansion engine is made for higher pressures than the compound engine, having only a high and low-pressure cylinder. The triple engine has three cylinders, a high and intermediate and a low-pressure cylinder as shown, marked H.P., I.P., and L.P. in Fig. 106. There are three valves—A, a high-pressure piston valve ; B, the intermediate piston valve ; and C, a low-pressure slide valve. All three valves are controlled by Stephenson link motion.

Referring to Fig. 107, a sectional end view through the low-pressure cylinder showing the air pump, this figure and the sectional elevation show clearly the elements of the triple-expansion reciprocating marine engine.

Plate III. illustrates a twin set of marine engines for a fast passenger twin-screw engine, and showing the reversing motion, feed pump, air pump, and condenser connections. They are interesting figures, as showing clearly high class designing in order to get the greatest power in an engine of small bulk and with ample strength of parts ; the large exhaust pipe acting as a stay between the two engines.

Plate IV. illustrates the machinery for a 25½-knot torpedo boat destroyer, developing about 8000 horse-power at 350 revolutions per minute. This machinery is being fitted into vessels at present building for the British Admiralty. On the right-hand side is clearly shown the thrust block and the massive link motion, also the air pump. This plate is from a photo in the engineering shop of Messrs. John I. Thornycroft.

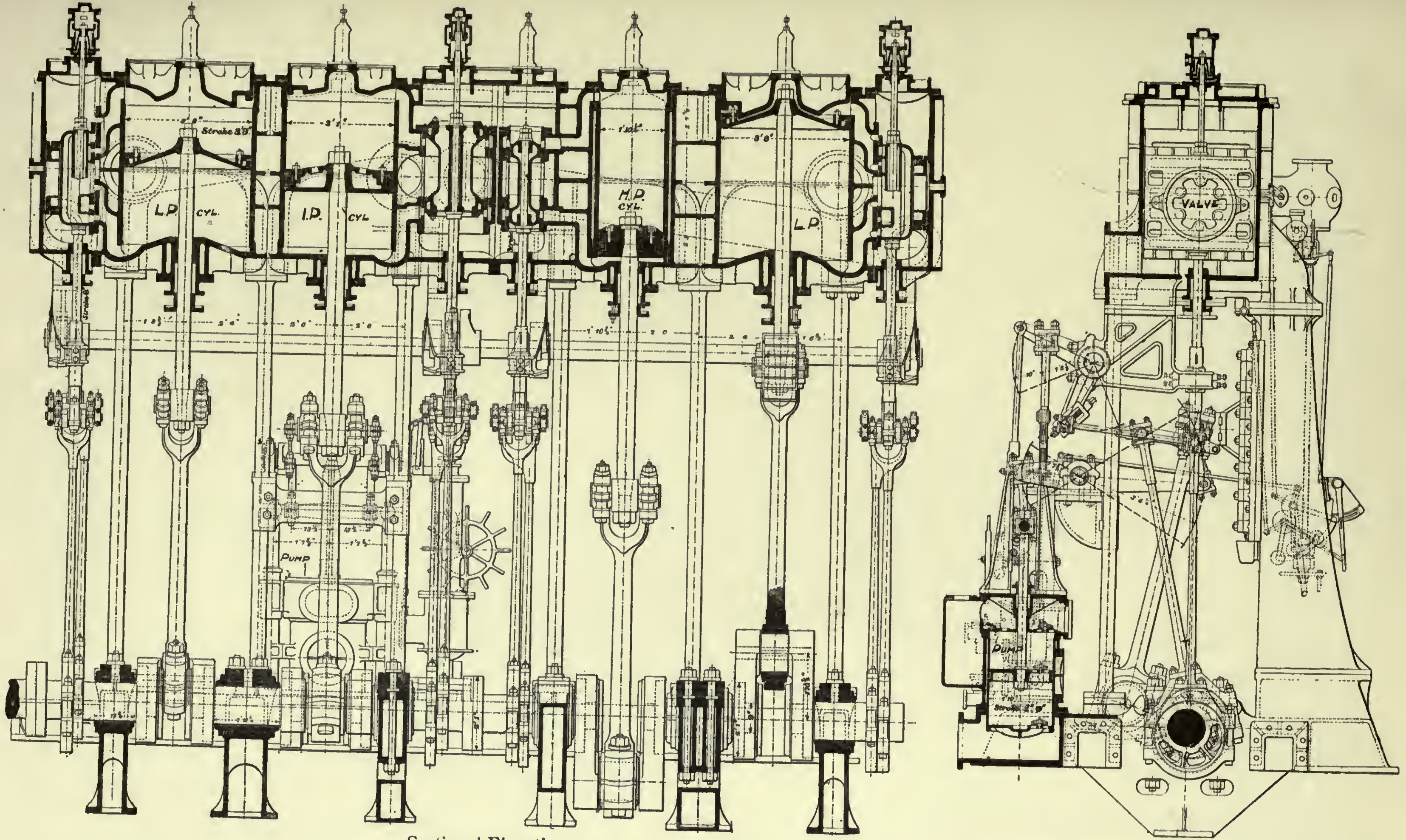
Plate V. represents one of eight torpedo boat destroyers, built by Messrs. Yarrow & Co. for the Japanese Government. The speed obtained by the vessels under British Admiralty conditions of trial was 31 knots, during a continuous run of three hours' duration, carrying a load of from 35 to 40 tons.

MARINE ENGINES OF A LINER

As an example of a foreign set of machinery for a first class steamer the illustration (Fig. 108) shows a section in transverse and side elevation. The two side cylinders are low-pressure, with the intermediate and high-pressure cylinder between.

By this design the engines are balanced. The engines are of the triple-expansion type, each set having four cylinders and four cranks, balanced on the Yarrow, Schlick, and Tweedy system. The sequence of the cylinders is low, high, intermediate, and low-pressure, reckoning from forward ; and their diameters in that order are 44, 22¼, 37, and 44 inches ; all having a piston stroke of 46 inches. Piston valves are fitted to the high-pressure and intermediate-pressure cylinders, and double-ported flat valves, having relief frames to the low-pressure cylinders. The valves are worked by the usual double-eccentric link motion. The reversing engines are of the direct-acting steam and hydraulic type. Slot levers are fitted to the reversing shaft to enable the cut-off in the different cylinders to be adjusted independently of each other. The front columns, adjacent to the centre of the ship (Fig. 108), are of cast iron, and of the ordinary split type, with separate guide faces. The shafting throughout is of mild steel, finished bright. The propellers have four blades of nickel steel with a cast-iron boss.

One air pump, 22 inches in diameter, and two feed pumps, 3¾ inches in diameter by 21-inch stroke, are fitted to each set of engines, and are driven by levers from the intermediate-pressure engine cross-head. The condensers are of cast iron, cylindrical in


L.P. CYL.
I.P. CYL
H.P. CYL.
L.P.
PUMP
VALVE
PUMP

Sectional Elevation.

Transverse Section through Low-Pressure Valve.

FIG. 108.—Four-Cylinder Triple-Expansion Balanced Marine Engine.

form, and placed in the wings of the ship. The tubes are of brass $\frac{3}{4}$ inch in external diameter, having a total condensing surface of 5978 square feet. The water is circulated through the tubes by a centrifugal pump. There is one to each condenser, and each is driven by an independent steam engine. A pair of Weir's direct-acting feed pumps and feed heater, with automatic control gear, are fitted in the engine-room.

The power developed on the measured mile was 4688 indicated horse-power—*i.e.* 2331 indicated horse-power in the starboard engine and 2357 indicated horse-power in the port engine, both engines running at 94 revolutions per minute. The mean speed of the vessel was 16.36 knots.

These engines were designed by Herr F. V. Kodolitch, and were built at the Arsenal Trieste.

It will be observed that the left-hand low-pressure cylinder is balanced by the left-hand intermediate cylinder. The two low-pressure valves balance, and the right-hand low-pressure cylinder balances the high-pressure cylinder, while the high-pressure piston valve balances the intermediate piston valve. By this means a very great improvement is the result in reducing the vibrations of the vessel.

The Frontispiece in this Volume shows a back view of one of Messrs. Westgarth & Richardson's triple-expansion 3-cylinder engines, showing water separators, traps, and pumps.

Plate VI. shows the front view of this marine engine, which has become a standard design on the East Coast as a triple-expansion engine. Special attention is given to lubricating the moving parts automatically, the effective drainage of water, and its return to the boiler. We have already described most of the details of such engines in Volume IV. These engines, which are of the triple-expansion surface condensing type, are designed for a boiler pressure of 180 lbs. per square inch, and are capable of indicating 1800 horse-power, at 70 revolutions per minute in regular work at sea. The cylinders are 25, 40, and 68 inches diameter by 48 inches stroke, the high-pressure being placed forward with the high-pressure and intermediate-pressure valves between the cylinders. By this arrangement the steam ports and passages are as short and direct as possible, and the space occupied by the engines is reduced to a minimum. A novelty in connection with the pistons is the design of the high-pressure and intermediate-pressure rings. These are of the "Ramsbottom" type, fitted with Morison's limit rings, which minimise the friction between the ring and the cylinder wall, and definitely control the possible wear of the piston ring and the cylinder to a predetermined amount. These limit rings are described in Volume IV.

The high-pressure cylinder is fitted with a piston valve, taking steam at the centre, so that the glands are not exposed to high-pressure steam; double ported slide valves are fitted to the intermediate-pressure and low-pressure cylinders, the travel of the valves being the same for all cylinders and the valve gear interchangeable throughout. Reversing gear of the "All Round" type is arranged on the centre front column, and the direction of rotation is controlled by means of a special piston valve attached to the reversing engine cylinder. The crank shaft, which is of the built type, is 13$\frac{3}{4}$ inches diameter, in three interchangeable pieces, and forged from ingot steel, the sequence of the cranks being high-pressure, intermediate-pressure, and low-pressure.

The centre back column is utilised as an eduction pipe from the low-pressure cylinder, so that the exhaust steam is uniformly distributed throughout the length of the condenser. As will be seen from the Frontispiece, the pumps are driven by means of levers and links from the cross-head of the low-pressure engine, in accordance with the makers standard practice, the two feed pumps being placed side by side at the forward end of the cross-head, and the bilge pumps aft. The air pump is of the Edward's design, 25 inches diameter by 27 inches stroke.

Copper main steam pipes have been practically discarded by the builders in favour of wrought iron or steel, provided with their "Universal Expansion Gland." This gland was described in Volume IV.

The engine-room auxiliaries include a Morison's radial evaporator, for supplying the necessary auxiliary feed water, and a surface feed heater with air and oil extractor is arranged in the line of feed pipes. The important detail of the evaporator designed by Mr. Morison for the supply of fresh water from soft water for the boilers may be referred to here. They may also be used for the supply of portable waters. There are several arrangements available, as steam, being taken from the boiler direct, the steam generated in the evaporator may be led to the steam chest of the low-pressure cylinder, to the main condenser, or to the hot well.

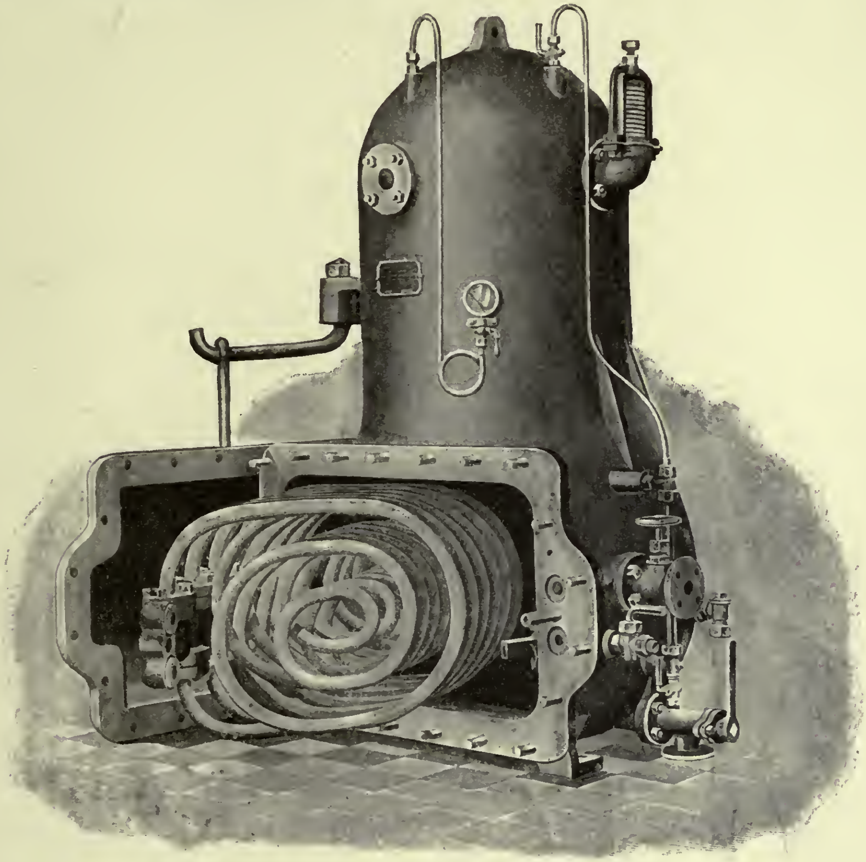


FIG. 109.—Morison's Radial Evaporator.

Water may be obtained from an evaporator for a nominal expenditure of coal, or very wastefully, depending entirely upon the arrangement adopted, and taking as unity the amount of coal necessary to produce a given quantity of water when the evaporator steam is condensed amongst the feed water; then the relative amount required to produce the same quantity when the steam is discharged into the low-pressure casing would be 12.3, and into the condenser 16.5—or, in other words, it takes 16½ times more coal to produce one ton when discharging into the condenser than when condensing the steam from the evaporator amongst the feed water.

This great difference in the economical production of fresh water is due to the fact that when steam from an evaporator is condensed amongst the feed water in the hot well all the heat in the steam is absorbed by the feed water, but when discharged into the condenser all the latent heat in the steam and a portion of its sensible heat is absorbed by the circulating water and is entirely lost. It is evident, therefore, that discharging steam from the evaporator direct to the condenser, although a cheap method as regards the cost of fitting up the apparatus on board ship, is distinctly the most uneconomical which could possibly be adopted; and although a connection to the condenser is convenient in port, yet at sea it should never be used.

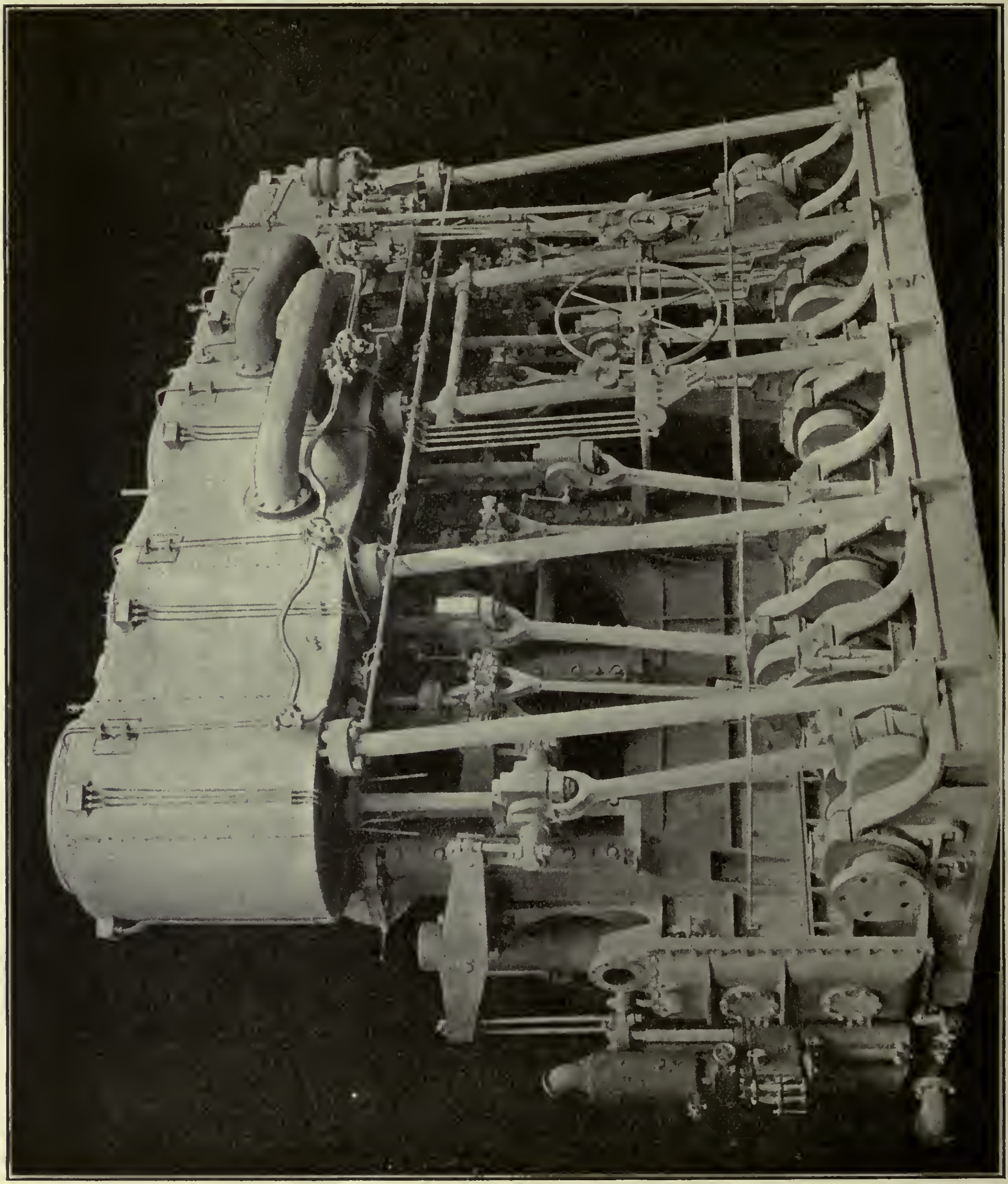


Fig. 110.—Front View of 5-Cylinder Quadruple-Expansion Marine Engine.

The latest design, which embodies many improvements, is illustrated at Fig. 109.

The success of this design has been most marked; in fact, the demand has so increased as to necessitate a special department being devoted to its manufacture.

As will be seen from the illustration, the evaporator comprises a lower horizontally arranged water vessel, provided with a vertical cylindrical extension forming a steam dome. The lower part is provided with a door, which is swung by a pivoted arm, to which it is attached, into such a position as will enable the coils to be withdrawn. The heating coils are detachably connected by means of flanged hydraulic joints to a horizontal standard forming the inlet for the steam and the outlet for the resulting water of condensation. The standard, which is in the form of a double channel, is closed at one end and hinged to a bracket attached to the inside of the evaporator; the other end is arranged with double spigot and faucet joints forming the connections for the steam inlet and water outlet, and secured by means of a central bolt.

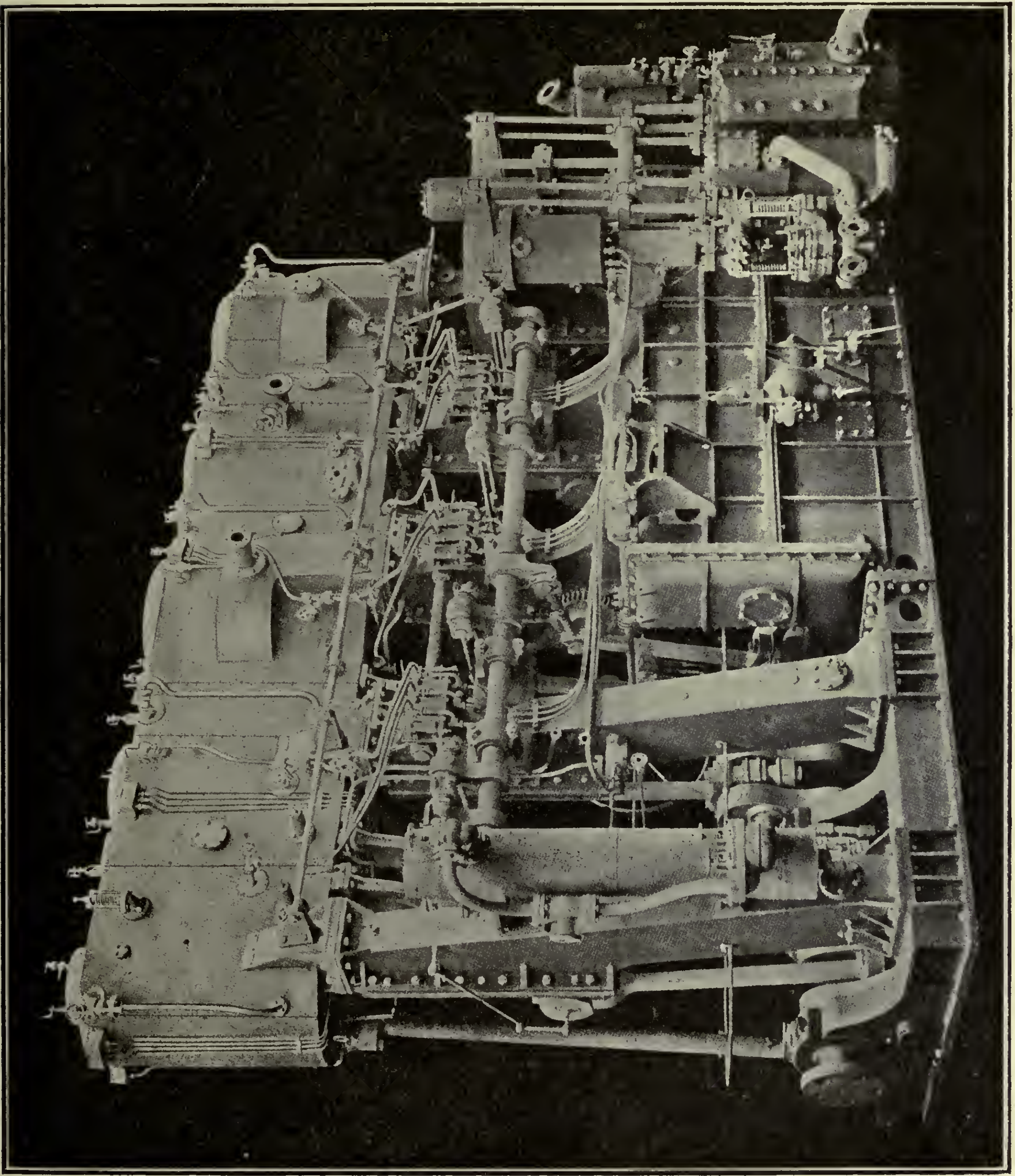


FIG. 111.—Back View of 5-Cylinder Quadruple-Expansion Marine Engine.

It will be seen that by simply removing one nut the standard with the attached coils may be swung outside of the evaporator for the purpose of examination or cleaning, and afterwards swung back again, an inclined bracket being arranged on the evaporator for sustaining the weight of the standard, thus ensuring the joints being readily re-made. All the joints being of the hydraulic or spigot and faucet type, liability to leakage is reduced to a minimum, the construction being of the safest and strongest description. Testing is a very easy operation, as by opening the steam valve and closing the drain the entire heating surface can be examined whilst under full boiler pressure, and all joints being in front are easily accessible for adjustment.

Referring to the Frontispiece, the pumps, air pumps, and feed pumps are seen at the far corner. On the near corner the cylinder with the dome-shaped top is the feed-water heater, and beneath is the hot well.

Fig. 110 is a front view of the Central Marine Engineering Company's marine engines for quadruple expansion, and Fig. 111 a back view of the same engines.

The engines have five cylinders, of diameters respectively of 17, 24, 34, 42, and 42 by 42-inch stroke, the high-pressure valve being of the piston type, and the others flat valves.

These engines are run by superheated steam supplied by boilers fitted with the "Central" superheater.

The working pressure in the boilers is 267 lbs. per square inch, generated in two single-ended boilers, worked with Ellis & Eaves' system of induced draught. Fitted in the uptake, immediately above the level of the highest row of tubes, is the "Central" superheater, a device designed and patented at the Central Marine Engine Works. It consists of a series of wavy tubes, as shown in the illustration (Fig. 112), in a cross and longitudinal sectional view in the ship, through which the steam is made to pass on its way from the boiler to the engine. The steam from the boiler enters at the top, where the gases are comparatively cool, and passes out to the main steam pipe at the lower end, where the gases are hottest. A temperature of 460° to 480° Fahr. is easily obtained. Above the superheater comes the air-heating tubes and casings, which, together with the fans, constitute the induced draught system.

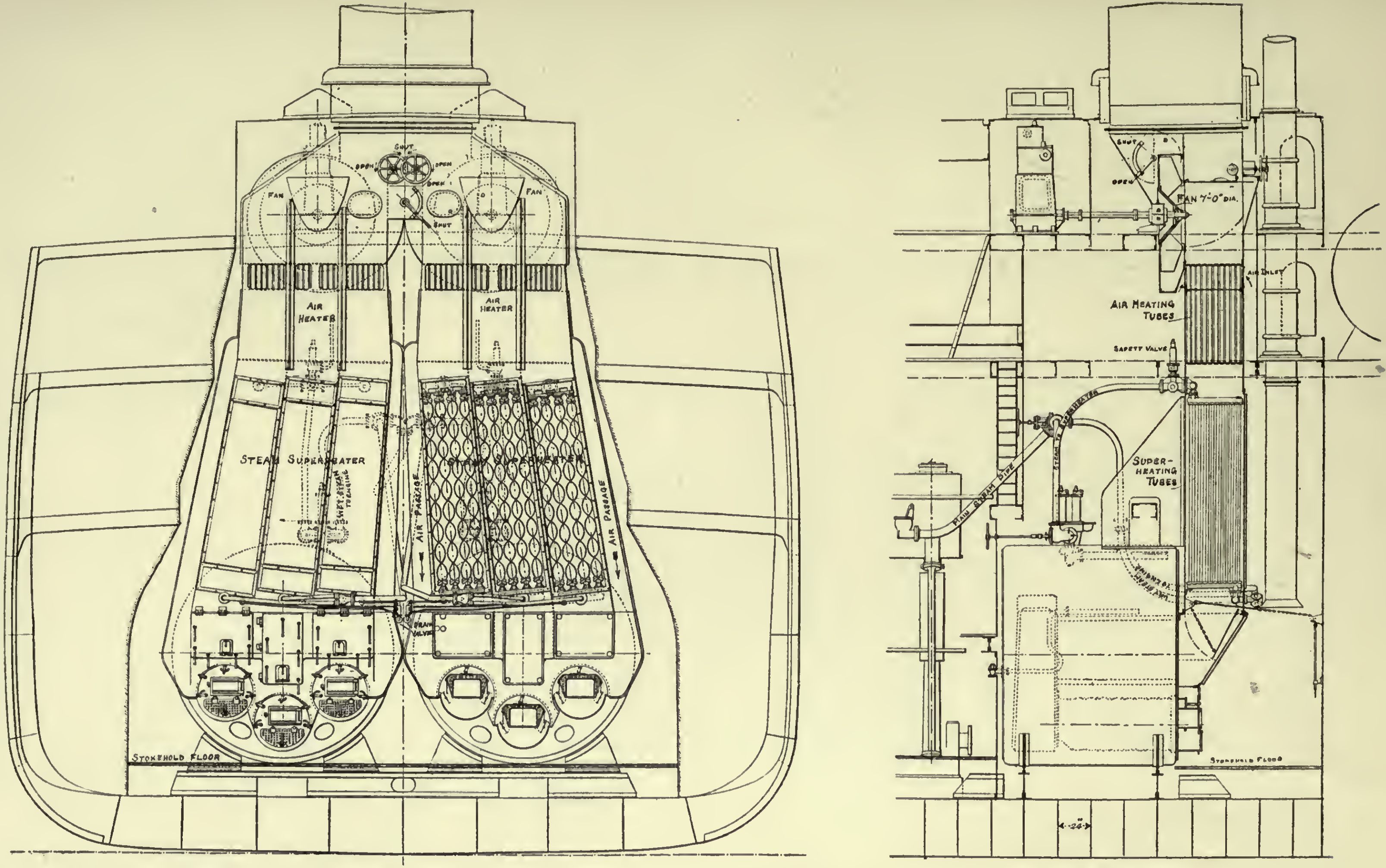
How great is the result to be obtained from this is seen from the following extract from a report received:—"The coal consumption on an extended trial from Hartlepool to Dover was at the rate of .97 lb. per indicated horse-power per hour."

In this arrangement the draught in the superheater is maintained by fans driven by separate engines. A more recent type is shown in the sectional view in Fig. 113, and in a front elevation in Fig. 114. In this type the natural draught is applied with regulating dampers and a bypass flue, the ordinary stokehole or closed ash pit forced draught is applied with this type and no fans on the hot gases. The subject of superheating has already been generally discussed in Volume IV.

THE TURBINE MARINE ENGINE

This engine has now been, without question, accepted as the marine engine of the present and future for steamers built for high speeds.

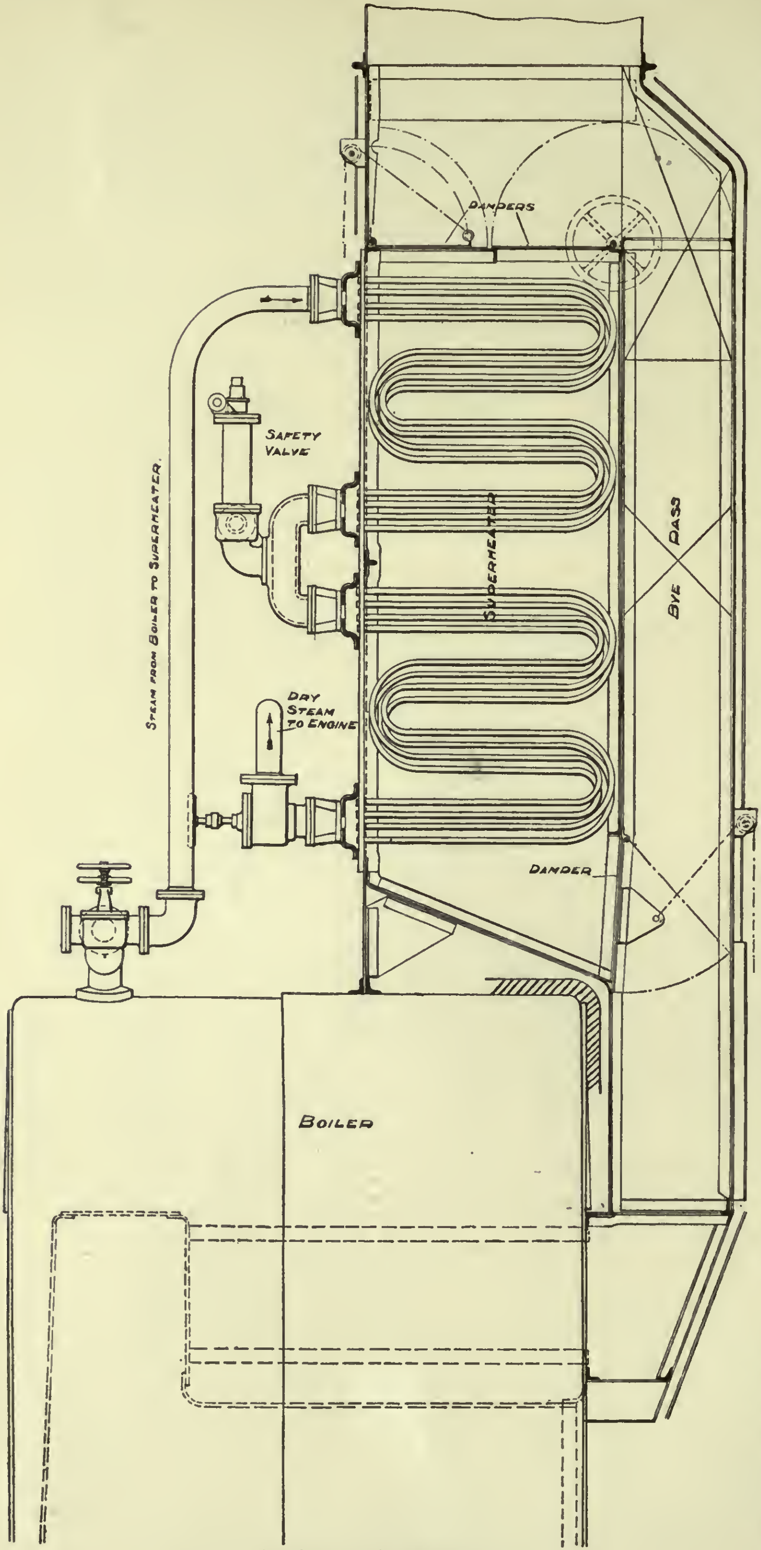
At this moment two of the largest Cunard Atlantic liners are approaching completion with turbine steam engines. Turbine vessels have been built for various services—between Dover and Calais, Newhaven and Dieppe, Dover and Ostend, Stranraer and Larne, Heysham and Belfast and the Isle of Man; a number of yachts have been built and fitted with turbines; other vessels for the Australian and New Zealand trade and for the Canadian lake service have been ordered; and finally, the Allan line have placed orders for two ships, and the Cunard Company for one intermediate steamer, of moderate speed, to be constructed also for propulsion with steam turbines. But the two new Cunarders, owing to their size and the high rate of speed to be attained, far surpass any of these ships, the capital expenditure involved in the construction of each being


SHUT
OPEN
OPEN
OPEN
SHUT
FAN
FAN
AIR HEATER
AIR HEATER
STEAM SUPERHEATER
WET STEAM TO ENGINE
AIR PASSAGE
AIR PASSAGE
DRAIN VALVE
STOKEHOLD FLOOR
SHUT
OPEN
FAN 7'-0" DIA.
AIR INLET
AIR HEATING TUBES
SAFETY VALVE
STEAM TO SUPERHEATER
MAIN STEAM PIPE
SUPER-HEATING TUBES
STOKEHOLD FLOOR
24"

Front Elevation.

Side Elevation.

FIG. 112.—Marine Boilers fitted with Superheaters and Induced Draught.



Sectiona. Side Elevation.

Fig. 113.—"Central" Marine Superheater.

something like ten times the cost of any of the vessels enumerated. These large vessels are 760 feet long, and are expected to attain a speed of 25 knots. The total horsepower required to develop this power is about 70,000 indicated.

At first it was thought that turbine engines would show a great saving in weight over reciprocating engines, but the saving in practice is not greater than 3 to 5 per cent. It must be remembered that the turbine only replaces the engine with pistons and cylinders, and requires heavier condensers, and all the boilers and accessories remain as before.

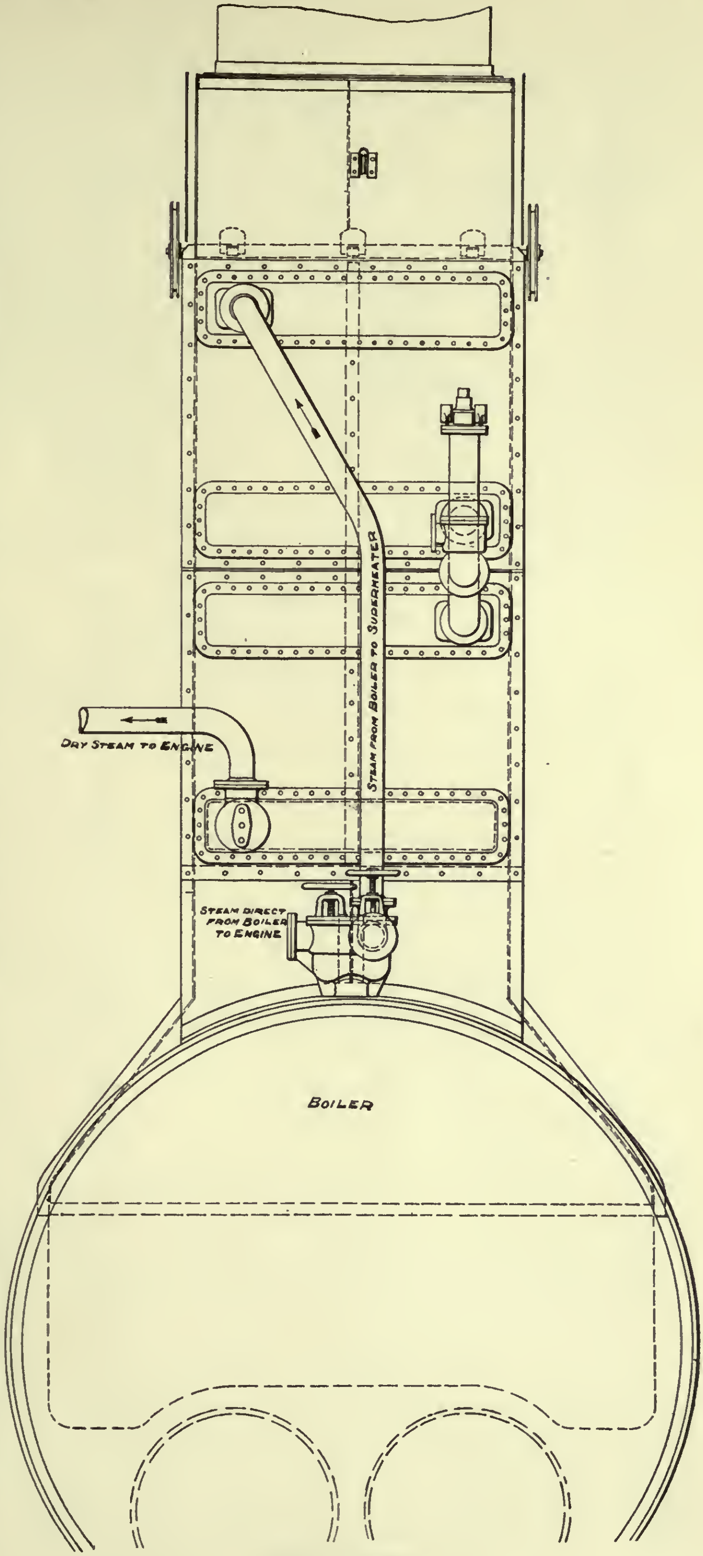
It is proposed to employ four shafts, each with a go-ahead propeller, and two of them fitted with reverse turbines.

The turbine still labours under the two disadvantages similar to those of the internal combustion engine: it is not economical working below full load, nor when of slow speed; and it is not reversible.

The author is still of opinion that the jet propeller would show better results with turbines than the screw propeller, for the reasons, first, that the jet can work economically with a slip of 50 per cent., while the screw slip must not exceed 25 per cent., and the jet propeller can reverse without reversing turbines, and the jets also can be used to steer the vessel. The failure of the jet in past experiments, wherein it was tested under quite mistaken notions and with unsuitable machinery, has given it an unwarrantable reputation for inefficiency.

Again, in merchant vessels the low economy when running under-loaded is of little importance, as these vessels run almost continually at full power. On a warship, however, the engines run almost continually at much below full power; hence in the former vessels this disadvantage is of little importance, while in the latter it is of very great importance. In order to meet this case the turbines are combined with reciprocating engines, the reciprocating engines used at slow speeds, and the two combined for full power.

Reversing at slow speed with small power reversing turbines is good enough for merchant vessels, but a warship should go astern almost as quickly as ahead; 30-knot boats are, as a rule, required—and are able—to steam astern at the rate of from 12 to 14 knots; it is possible, indeed, that even a higher rate may be got under certain conditions. The stress on the ship and machinery when running astern at high speed is very great; but the officers of a destroyer, after firing a torpedo successfully, will probably accept the possi-


DRY STEAM TO ENGINE
STEAM FROM BOILER TO SUPERHEATER
STEAM DIRECT FROM BOILER TO ENGINE
BOILER

Front Elevation.

FIG. 114.—"Central Marine Superheater.

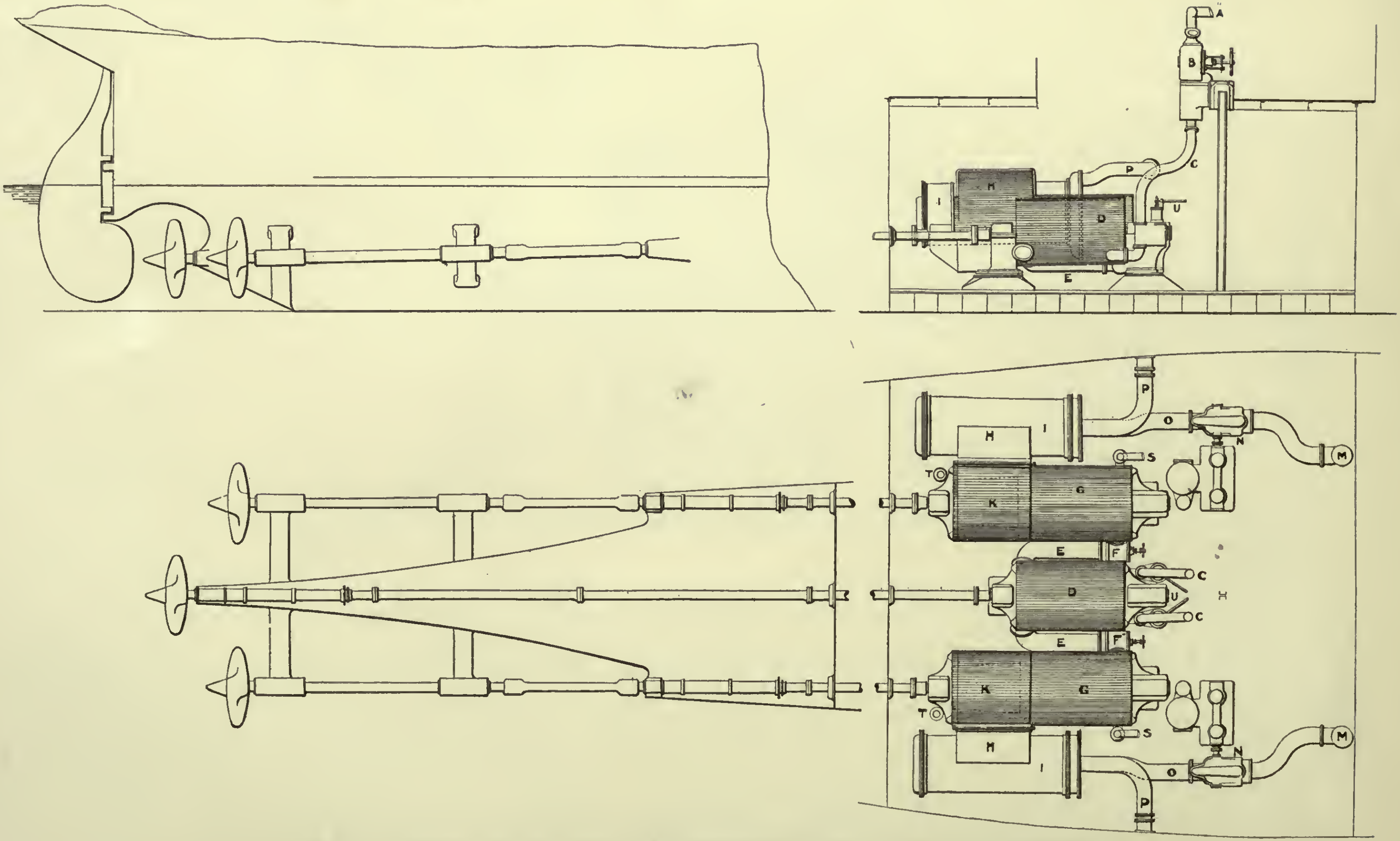

A
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FIG. 115.—Elevation and Plan showing Arrangement of Turbines on Cross Channel Steamer.

bilities of trouble from machinery breakdown in preference to the chance of being hit by the enemy if they waited to turn their craft. In cruisers, speeds astern of from 14 to 16 knots are usually attained on trials. The *Amethyst* has been run astern at 11 knots. The ratio of astern to ahead power is not at all indicated by the proportion of 11 knots astern to 23½ knots ahead, the form of ship materially affecting the speed astern for a given power. The power which may be exerted in stopping the ship when going ahead is very considerable, and would be quite satisfactory so far as the requirements of the merchant service are concerned. At the same time, there are enormous potentialities for a reversible turbine. We have seen in Volume III. how a turbine can be made reversible only by using flat inefficient blades.

High speed of rotation is a difficulty which is now being overcome, as the propellers of the Cunard ships will probably run at about 140 revolutions; and although this is considerably higher than in ordinary merchant work, there is no reason for objection. The influence on the economy of the turbine, however, has yet to be determined. High speed of revolution involves a smaller propeller, deeper immersion, less cavitation, and therefore a higher propulsive efficiency. In the merchant service, where vessels have often to run light, this is of special importance; indeed, it is not uncommon for steamers in ballast to make long voyages with the propeller only half immersed, which means a great reduction in efficiency. With the hydraulic jet propeller it does not matter whether the jet is immersed or not.

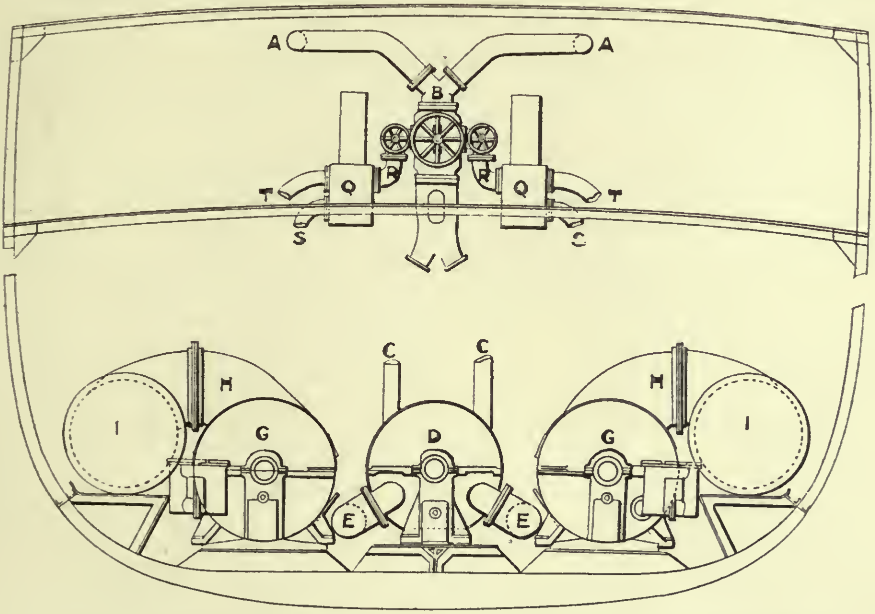


Fig. 116.—Cross Section showing Arrangement of Turbines on Channel Steamer.

The arrangement of turbines in a vessel may be gathered from the plan and elevation shown in Fig. 115, and the cross section (Fig. 116), as adopted in the turbine channel steamer *The Queen*, and which is applicable to most vessels fitted with the turbine system of propulsion. There are three turbines, namely, one high-pressure in the centre of the ship, and two low-pressure, one on each side of ship. Each turbine drives a separate shaft, with one propeller on each shaft, three in all. Inside the exhaust casing of each of the low-pressure cylinders a reversing turbine is fitted. In ordinary going ahead, the steam from the boilers is admitted through a suitable regulating valve to the high-pressure turbine, and, after expanding about 5-fold, it then passes to each of the low-pressure turbines in parallel, and is again expanded in them about 25-fold, and then passes to the condensers. The total expansion ratio being 125-fold.

When coming alongside a jetty or manœuvring in or out of harbour, the outer shafts only are used, and the steam is admitted by suitable valves directly into the low-pressure turbines, or alternately in the reversing turbines as may be desired. With this arrangement the port or starboard engines are capable of being worked ahead or astern independently of each other and of the high-pressure turbine (the high-pressure turbine rotating idly in a vacuum whilst the vessel is manœuvring).

The turbine cross channel steamer *The Queen* has exceptionally great manœuvring power. On her trial trip on the Clyde, on the 12th June, when steaming continuously astern, she attained a speed of about 13 knots. Starting and stopping trials were also carried out, and the vessel, when going over 19 knots per hour, was brought to a dead stop in 1 minute 7 seconds after the telegraph order was given to the engine-room, and the distance she travelled in this time was equal to only two-and-a-half times her own length.

ARRANGEMENT OF TURBINE MACHINERY SUITABLE FOR A CROSS CHANNEL STEAMER (8000 INDICATED HORSE-POWER)

A. Steam from boiler.
B. Main regulator valve.
C. Steam to high-pressure turbine.
D. High-pressure turbine.
E. Exhaust from high-pressure turbine to automatic closing valve.
F. Automatic closing valve.
G. Low-pressure turbine.
H. Exhaust to condenser.
I. Condenser.
K. Astern turbine.
L. Air pump.
M. Main inlet to circulating pump.
N. Circulating pump.
O. Circulating pump discharge to condenser.
P. Condenser discharge overboard.
Q. Manœuvring valve or low-pressure ahead and astern steam.
R. Steam to manœuvring valve.
S. Steam to low-pressure turbine.
T. Steam to astern turbine.
U. Governor valve.

MIDLAND RAILWAY COMPANY'S TURBINE VESSELS

This company built two pair of steamers exactly alike. Only one pair was fitted with turbines, and the other pair with cylinder and piston engines. A very fair comparison can therefore be made between the two systems of propulsion. The *Londonderry* and *Manxman* were fitted with Parsons turbines; the *Antrim* and *Donegal* were fitted with cylinder and piston engines. The *Manxman* differs slightly from the other three in breadth and in machinery.

The principal dimensions of the three vessels are as follow:—Length on waterline, 330 feet; breadth, moulded, 42 feet; depth, moulded to upper deck, 18 feet, and to promenade deck, 25 feet 6 inches. The vessels are built throughout of Siemens-Martin steel, to the latest Board of Trade regulations for channel steamers. The hull in each case is divided into compartments by eight water-tight bulkheads.

Taking the main points, the *Antrim* and *Londonderry* are of exactly the same form and scantlings, with boilers of the same size, the type of engine and steam pressure only differing. The weight of all machinery—*i.e.* everything associated with the propelling of the ship—is, in the former, practically 730 tons, as compared with 575 tons in the latter. This difference, totalling 155 tons, is due first to the reduction of scantlings in boilers due to difference in pressure: the *Antrim's* boilers weighed, with water, 460 tons; the *Londonderry's*, 15 per cent. less. The main reciprocating engines weighed 210 tons, as compared with 160 tons for the turbine machinery, and the shafting respectively about 60 and 25 tons. In the *Manxman* the designers decided to adopt the same steam pressure as in the *Antrim* and *Donegal*—200 lbs., and the turbines were proportioned

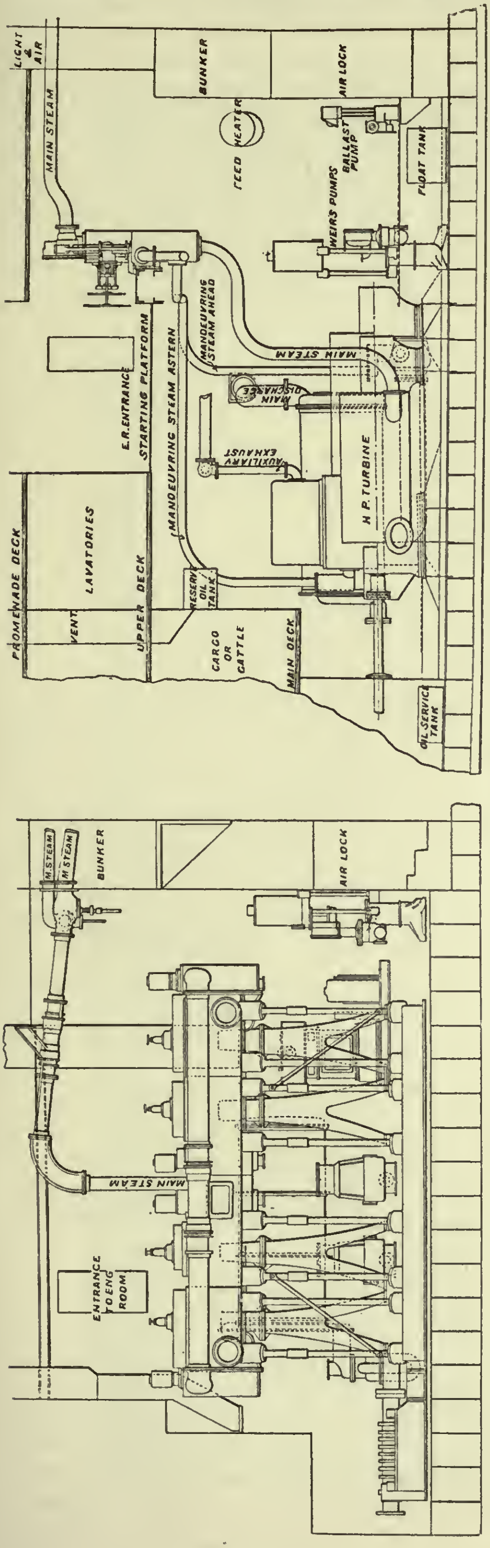

LIGHT & AIR
MAIN STEAM
BUNKER
AIR LOCK
FEED HEATER
BALLAST PUMP
WEIRS PUMPS
FLOAT TANK
MANOEUVRING STEAM AHEAD
MAIN STEAM
MAIN DISCHARGE
AUXILIARY EXHAUST
E.R. ENTRANCE
STARTING PLATFORM
MANOEUVRING STEAM ASTERN
H.P. TURBINE
PROMENADE DECK
LAVATORIES
UPPER DECK
VENT
RESERVE OIL TANK
CARGO OR CATTLE
MAIN DECK
OIL SERVICE TANK
M. STEAM
M. STEAM
BUNKER
AIR LOCK
MAIN STEAM
ENTRANCE TO ENG ROOM

FIG. 117.—Elevation of Reciprocating Marine Engines and Marine Turbines.

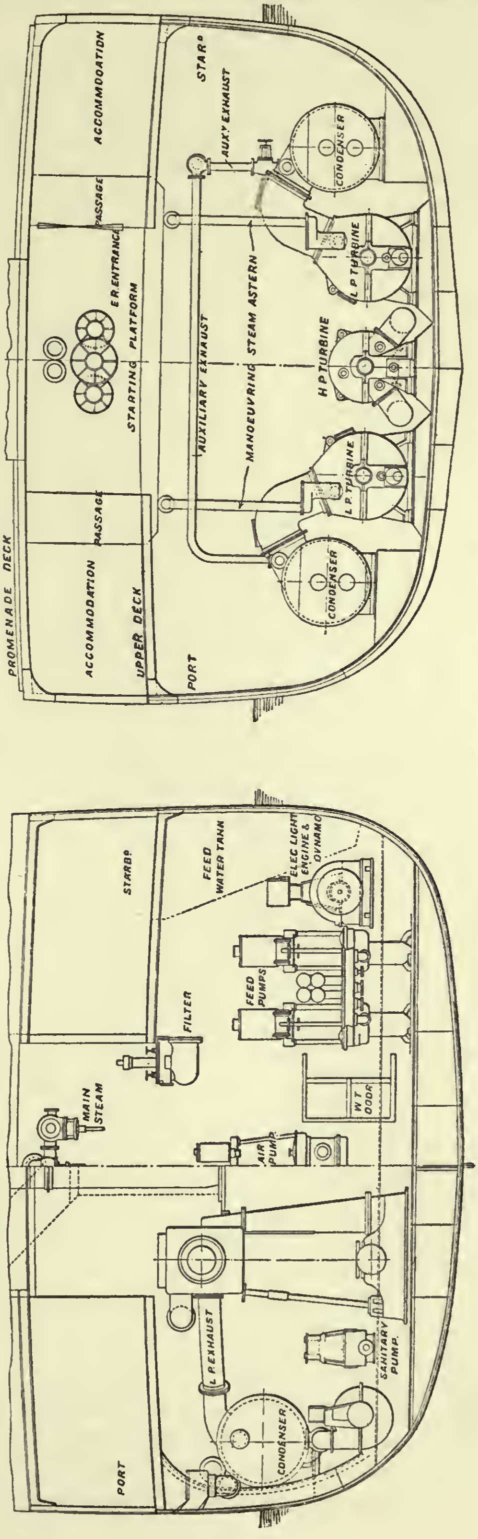

ACCOMMODATION
STARᴰ
AUXY EXHAUST
CONDENSER
PASSAGE
E.R. ENTRANCE
L.P. TURBINE
STARTING PLATFORM
AUXILIARY EXHAUST
MANOEUVRING STEAM ASTERN
H.P. TURBINE
L.P. TURBINE
PASSAGE
CONDENSER
PROMENADE DECK
ACCOMMODATION
UPPER DECK
PORT
STARBᴰ
FEED WATER TANK
ELEC LIGHT ENGINE & DYNAMO
FEED PUMPS
FILTER
MAIN STEAM
W.T. DOOR
AIR PUMP
L.P. EXHAUST
SANITARY PUMP
CONDENSER
PORT

FIG. 118.—End View of Reciprocating Marine Engines and Marine Turbines.

accordingly. There is thus not such a great saving in weight; but this and other modifications, introduced for the first time in the *Manxman*, improved the economy and increased the speed to an extent which fully justified the forfeiture of some of the gain in weight in the *Londonderry*.

The comparative drawings (Figs. 117, 118, and 119) show that the turbine machinery occupies 2 feet less of the length of the ship than the reciprocating engines; but in the *Manxman's* engine-room there is a very considerable floor area for the working of the machinery in excess of that to be found in similar steamers with reciprocating engines. There is less head-room needed, especially in the *Manxman's* arrangement; for instead of having the starting platform on the upper deck level, it is on the engine-room floor level, which is better from all three points of lighting, ventilating, and over-seeing.

As to speed, we take the performance of the *Antrim* as typical of the results of the ships with reciprocating engines—those of the *Donegal* being practically identical—for purposes of comparison with those of the *Londonderry*. In the latter the Parsons turbines were designed to give equal speed with less weight, and at the pressure of 150 lbs., the turbine manufacturers claiming that there was no material gain from higher steam pressures. The saving in displacement from all causes in the *Londonderry* was about 180 tons, and she had the advantage of this in the several trials.

Here is a comparison of speeds:—

	Antrim.	*Londonderry.*
With two double-ended boilers in use—six hours' trial	20.6 knots	21.6 knots
Ditto—mean on measured mile . . .	21.0 knots	21.9 knots
With two double and one single-ended boilers in use—mean on measured mile .	21.9 knots	22.27 knots

It will be noted that while the *Londonderry* had a speed practically one mile per hour faster than the *Antrim* when using only the two double-ended boilers, the turbines seem to have been unable to utilise in effective work the greater steam supply provided by the two double and one single-ended boilers. It should be remembered, however, that the designer's original terms of specification were that the speed guaranteed—20 knots—was to be maintained for six hours, with the two double-ended steam generators only, the single-ended boiler being regarded as a reserve to be used to ensure reliability in time-keeping on service. The *Manxman's* machinery was not only designed to use a higher steam pressure than the *Londonderry*, but also to take all the steam generated by the three boilers. Her turbines are therefore, as already stated, heavier and more powerful, and on her official trial she got ¾ nautical mile per hour more than the *Londonderry* when using all boilers. The comparative results for the maximum speed of both ships are as follow:—

	Manxman.	*Londonderry.*
Steam pressure at the boilers . . .	150 lbs.	200 lbs.
,, in high-pressure receiver . . .	135 lbs.	180 lbs.
,, in low-pressure receiver . . .	12 lbs.	19 lbs.
Vacuum	28 inches	29 inches
Revolutions, centre shaft (with high-pressure turbine)	670	530
Revolutions, side shafts (with low-pressure turbine)	750	610
Speed	22¼ knots	23 knots

The reciprocating-engined ship, on the other hand, made on the corresponding trial, with rather less displacement and the same boiler power, 21.9 knots, so that the *Manxman* is 1 mile per hour faster. In the *Manxman's* trials the speed of 23 knots was attained on three double runs on the measured mile at different stages of the two

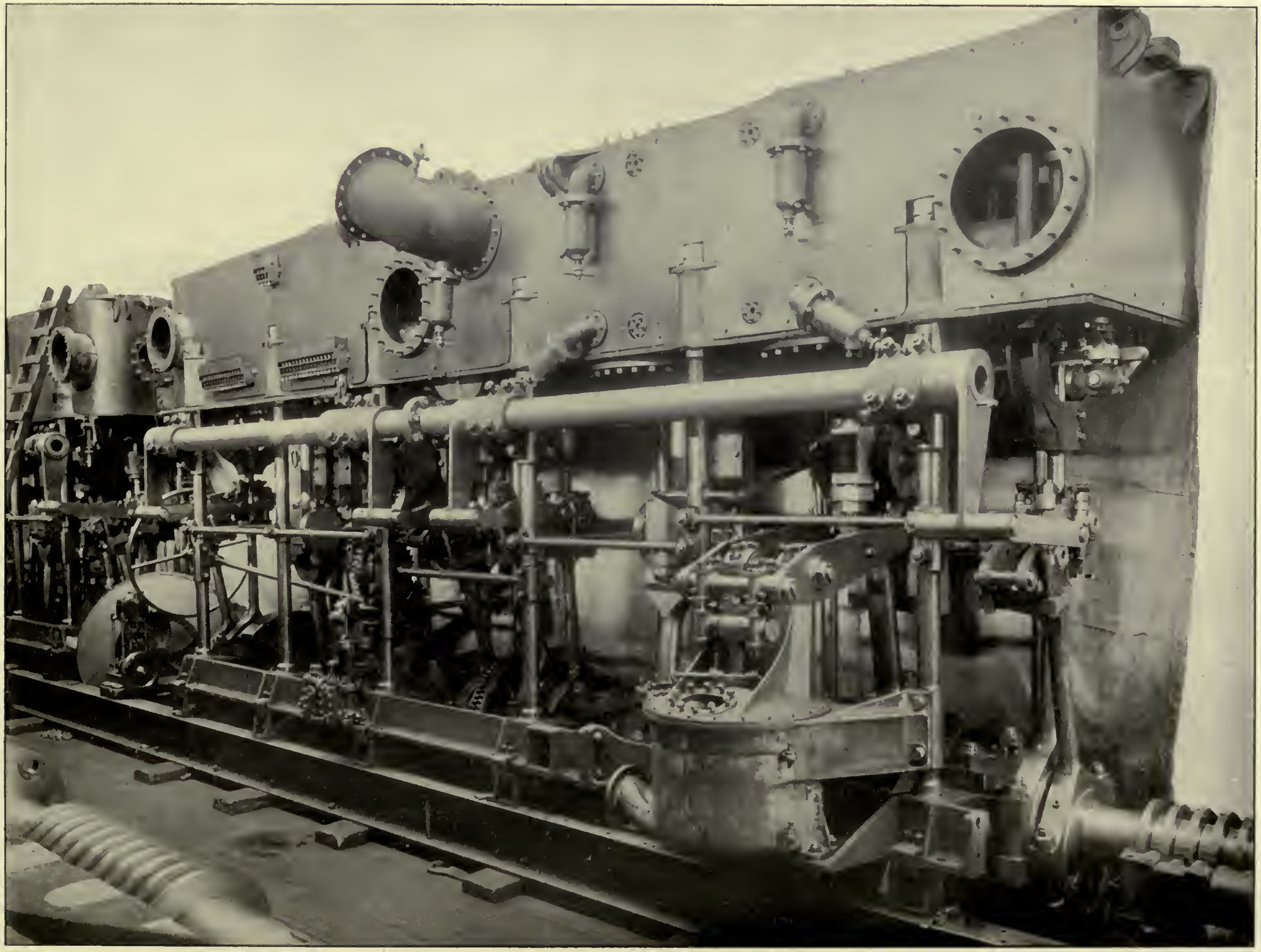


Plate IV.—8000 H.-P. Engines for Torpedo Boat Destroyer.

days' trials, and her speed on her official six hours' run was 22.65 knots. She is the fastest turbine-driven merchant steamer afloat.

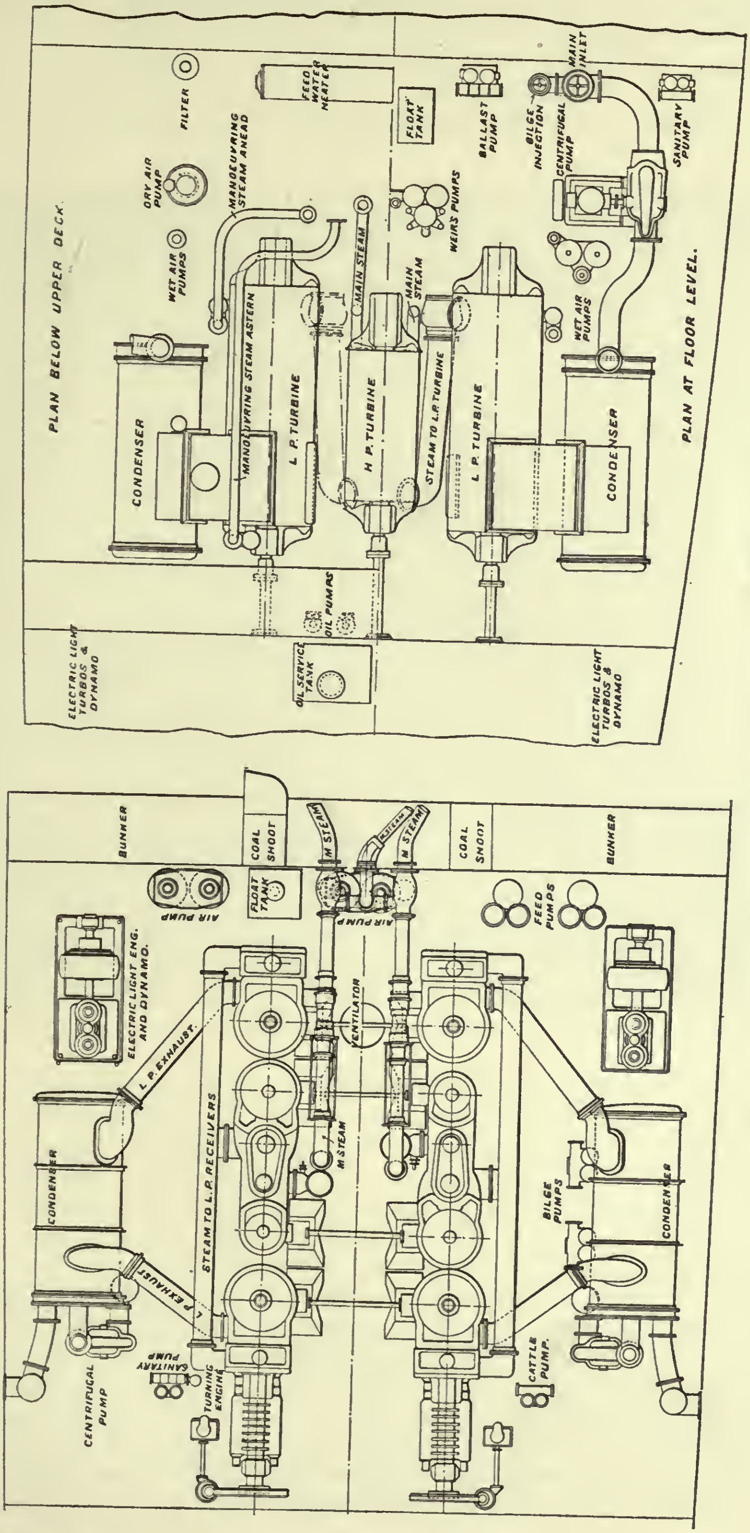

PLAN BELOW UPPER DECK.
PLAN AT FLOOR LEVEL.
FILTER
DRY AIR PUMP
WET AIR PUMPS
MANOEUVRING STEAM AHEAD
MANOEUVRING STEAM ASTERN
FEED WATER HEATER
FLOAT TANK
BALLAST PUMP
BILGE INJECTION
MAIN INLET
CENTRIFUGAL PUMP
SANITARY PUMP
WEIRS PUMPS
MAIN STEAM
CONDENSER
L. P. TURBINE
H. P. TURBINE
STEAM TO L.P. TURBINE
L. P. TURBINE
WET AIR PUMPS
CONDENSER
OIL PUMPS
OIL SERVICE TANK
ELECTRIC LIGHT TURBOS & DYNAMO
ELECTRIC LIGHT TURBOS & DYNAMO
BUNKER
COAL SHOOT
M STEAM
M STEAM
COAL SHOOT
BUNKER
AIR PUMP
FLOAT TANK
AIR PUMP
FEED PUMPS
ELECTRIC LIGHT ENG. AND DYNAMO.
L. P. EXHAUST.
VENTILATOR
STEAM TO L.P. RECEIVERS
M STEAM
CONDENSER
L. P. EXHAUST
BILGE PUMPS
CONDENSER
SANITARY PUMP
TURNING ENGINE
CENTRIFUGAL PUMP
CATTLE PUMP.

FIG. 119.—Plans of Reciprocating Marine Engines and Marine Turbines.

There are in the vessel three sets of expansion turbines; the centre shaft is driven by the high-pressure turbine, and each of the two side shafts by a low-pressure turbine, the astern-driving turbines being mounted also on the side shafts. These latter take steam direct from the boiler. The general arrangement is very much the same as previously described in connection with the *Londonderry*, with this important exception, that the proportions of the machinery in the *Manxman* were increased to utilise the higher pressure and the greater volume of steam supplied by all three boilers.

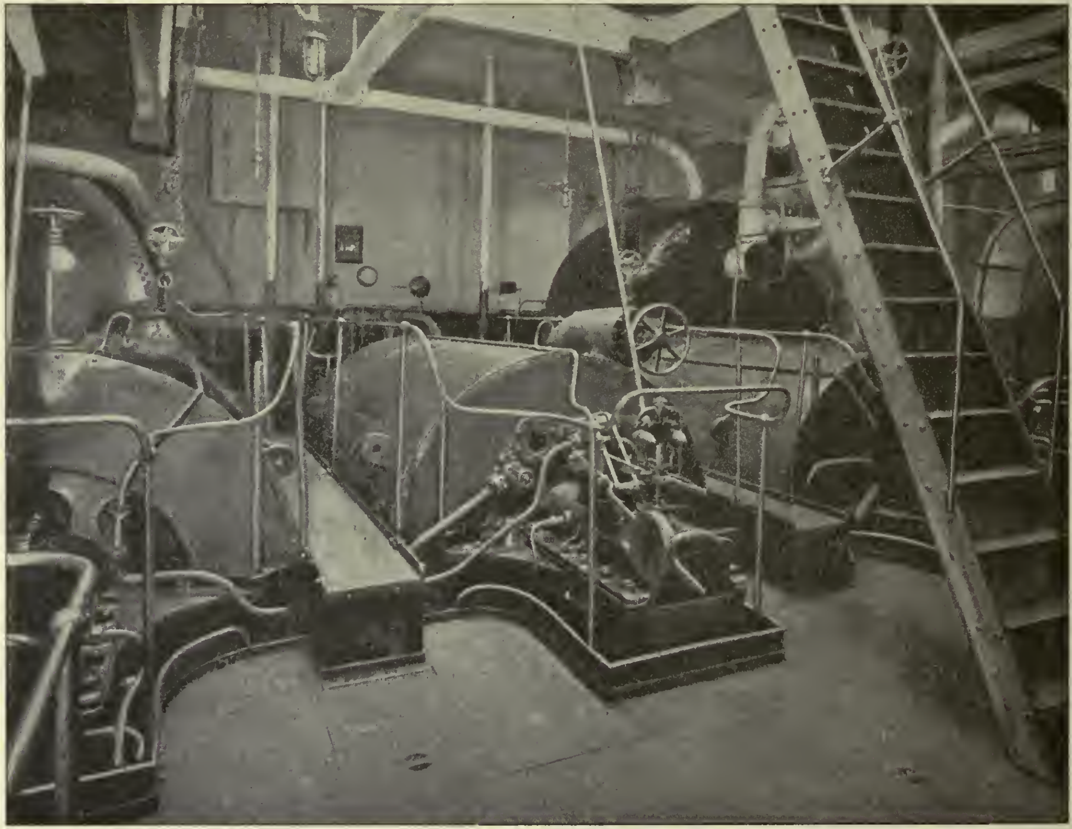


FIG. 120.—Engine-Room of Turbine-driven Steamer, looking towards the Port Side.

A further trial was made with the *Manxman*, giving the following results:—

Mean speed of two runs	23.141 knots
Boiler pressure per square inch	192 lbs.
Steam in high-pressure turbine	180 lbs.
,, in low-pressure turbine, port	20 lbs.
,, ,, ,, starboard	20 lbs.
Vacuum in condenser, port	28.25 inches
,, ,, starboard	28.4 inches
Revolutions per minute, high-pressure turbine	533
,, ,, low-pressure turbine	609
Temperature of feed water leaving heater	190° Fahr.
Air pressure in stokehold	1.5 inches

Fig. 120 shows view looking towards the port side of the ship, and shows all three turbines. The high-pressure turbine is in the centre, and the mechanism connected with the governing is clearly indicated. The governors, which are mounted on each shaft, only come into operation in the event of a breakdown, or of excessive racing of the propeller shafts. The system of centrifugal governor generally adopted in Parsons' turbines moves a small relay plunger which regulates the steam admitted to a relay, which in turn actuates the main throttle valve, generally of the balanced double-beat type. The exhaust from the steam relay is utilised for the steam packing of the end glands. Thus the governor, having only to move the small plunger, has very little work to do, and therefore can be made very sensitive. The sensitiveness is still further increased by keeping the whole governor gear in slight movement by connecting one of the pivots of the levers with a cam. These movements are so rapid as not to affect the even turning moment of the turbine. On the top of the high-pressure turbine is the by-pass valve, which is used for the admission of steam at full pressure to an intermediate stage on the high-pressure turbine, so as to increase the power—at the expense, however, of economy. It should be mentioned here that during the trials of the *Manxman* no such high-pressure steam was admitted at the intermediate stage, the turbines being worked to the full degree of expansion. The pipes for the admission of steam to the glands, as well as the smaller pipes for oil and water service, are also shown. The passage way between the turbines leads to the after end of the engine-room, where the oil pumps are placed, as well as to the tunnels. The graduated vertical bars shown immediately against the forward end of all three turbines are for guiding the casing when the upper portion is being moved in connection with examination or repairs of the internal mechanism.

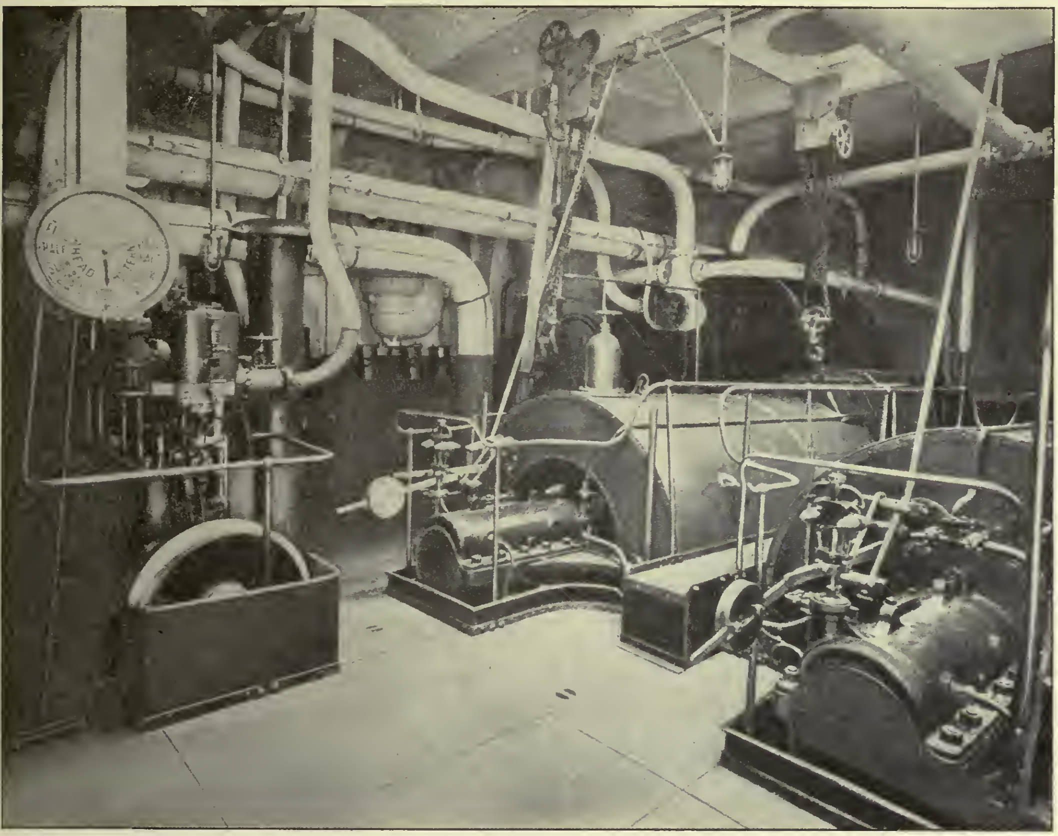


FIG. 121.—View of the Starboard Side of Engine-Room of Turbine-driven Steamer.

In Fig. 121 the high-pressure or centre turbine is shown to the right of the engraving, the starboard low-pressure turbine being in the centre of the view. To the left, under the engine telegraph, is seen the air-pump engine, behind which is the circulating pump; both are driven from the shaft of the same engine. The starboard condenser is seen as a black mass in the background, with its connection to the low-pressure turbine by means of a large exhaust bend. The pipe which occupies a prominent position near the forward end of the low-pressure turbine is for supplying steam direct to the low-pressure turbine for manœuvring purposes. By this supply pipe steam of full pressure may be supplied to the side go-ahead turbines, so that, if desired, all three turbines in the ship may be worked as high-pressure systems. Above this pipe there is a steam lead to the go-astern turbine, which is mounted on the side shafts abaft the low-pressure go-ahead turbine.

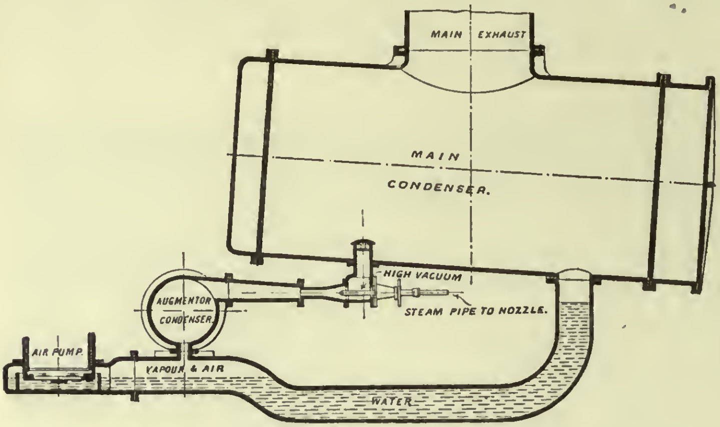


FIG. 122.—Condenser fitted with Auxiliary Jet Ejector.

The augmentation of the vacuum by an additional jet ejector is of considerable interest. It is shown how it is connected to the main condenser in Fig. 122. This jet ejector condenser removes the traces of air and vapour left by the air pumps, which therefore need not be so large as when they are used without an augmentation ejector. The remaining steam from the turbine at full load, together with the air extracted, is cooled down and condensed by the auxiliary condenser, which is generally supplied with water in parallel with the main condenser. Condensation in a condenser takes place much more rapidly and effectually if the air is thoroughly extracted than if there is much air present, as the air seems to form a blanket round the tubes, and prevents the steam from getting free access to them.

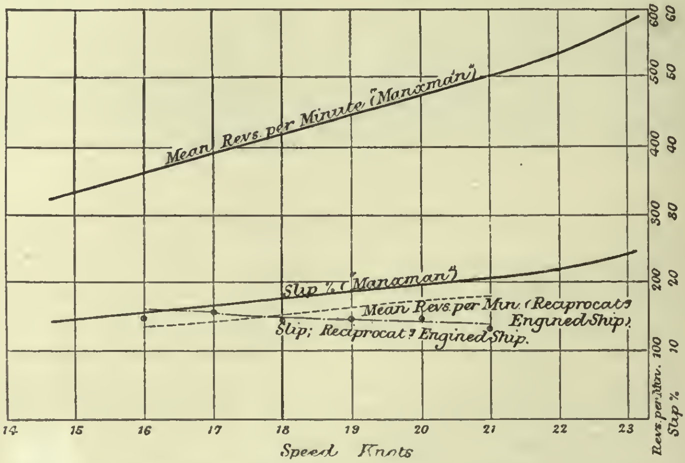


FIG. 123.—Revolutions and Slip at Progressive Speeds of Turbine-driven Steamer *Manxman*, and Reciprocating-engined Steamer.

In view of the great interest now being taken in the question of propeller efficiency, we give, in Fig. 123, a diagram showing the revolutions and percentage of slip of propeller at the progressive speeds of the *Manxman*. The results show that at a speed of 15 knots the slip is about 14.8, whilst at a speed of 23 knots, when the revolutions run up to about 580, the slip is about 24¼ per cent. This slip at the top speed appears to be, if compared with ordinary performances, somewhat excessive. The apparent slip generally looked for at the higher speeds is taken usually at between 13 and 14 per cent., but is frequently somewhat higher than this. Some cruisers of practically similar speed to the *Manxman*, with very fine lines and good coefficients of performance, have obtained their best results with an apparent slip of from 14 to 16 per cent. Notwithstanding this apparently excessive slip, the performance of the *Manxman* at the top speed is certainly remarkable.

The results of the reciprocating-engine propellers are very satisfactory; the slip varying only between 15 per cent. and 13.6 per cent., the latter being the result at the highest speed; but this was only 21 knots. How the result would have worked out for 23 knots, had such a speed been attainable with the machinery on board, it is not easy to calculate.

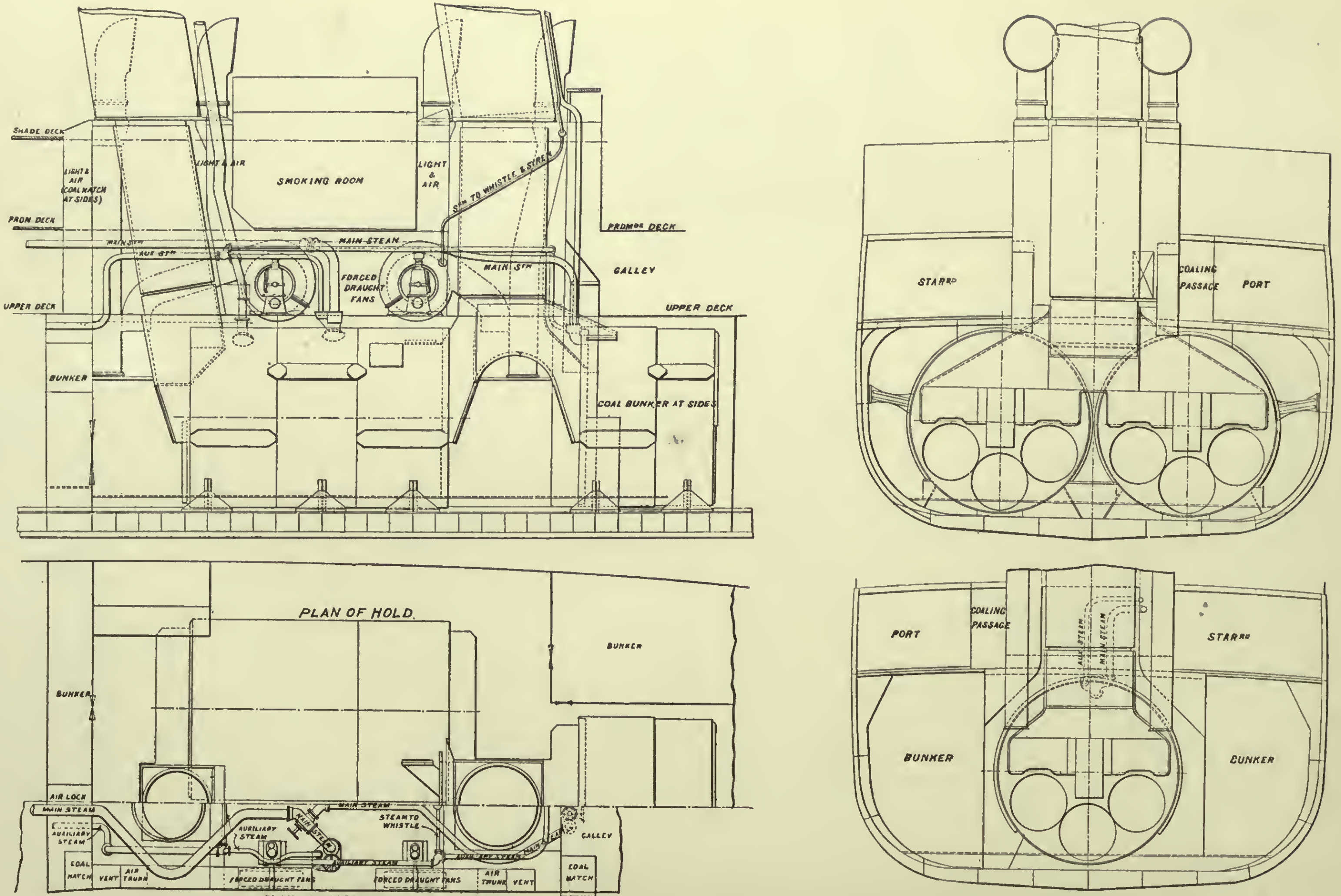
The boilers of all four ships are illustrated in Fig. 124. There are two double-ended boilers and one single-ended boiler, and the principal dimensions of these are given in parallel columns:—

BOILERS OF MIDLAND STEAMERS.

	Double-ended.	Single-ended.
Number	2	1
Length	22 feet	11 feet 6 inches
Diameter	15 feet 7 inches	15 feet 7 inches
Number of furnaces	6	3
Diameter of furnaces	3 feet 11 inches	3 feet 11 inches
Length of grate	6 feet 6 inches	6 feet 6 inches
Heating surface	4984 square feet	2493 square feet
Grate area	161 square feet	80 square feet
Total heating surface in each ship	12,461 square feet	
Total grate area in each ship	402 square feet	

The two double-ended boilers are placed side by side in the after part of the boiler-room, while the single-ended boiler is fitted in a recess in the centre of the boiler-room forward, with large coal-bunkers on each side, as shown in the cross section (Fig. 124). The boilers are worked under forced draught, the stokeholds being closed, and four fans are located on the upper deck, as shown in the longitudinal section, and on the plan. In the *Antrim* and *Donegal* the fans are driven by electric motors, and in the *Londonderry* and *Manxman* by high-speed steam engines, supplied by Messrs. Paul & Co., Dumbarton. The maximum pressure attained on the trials of the four boats did not exceed 1¼ inch of water at the fans. The arrangement of steam pipes is well shown on the upper deck plan, as well as in the longitudinal section.

The reciprocating machinery of the *Antrim* and *Donegal* differs only in detail. The engines of the latter are of the 4-cylinder triple-expansion type, each set driving a 3-bladed propeller. The high-pressure cylinders are 23 inches in diameter, the intermediate 36 inches, and the low-pressure 42 inches, the length of stroke being 30 inches. Liners are fitted in all the cylinders. The slide-valves are of the piston type for the high and intermediate-pressure cylinders, and of the flat-faced double-ported design for the low-pressure cylinders. The valve gear is of the usual double-eccentric double-bar link-motion form, and the reversing engines are of the direct-acting steam and hydraulic type. The crank and line shafting is of mild forged steel. The crank shafts are of the solid type bored hollow, and consist for each engine of two double-throw cranks coupled together. The condensers are separate from the main engines; the shells consist of steel plates riveted together, and the end casings and doors are of brass.


SHADE DECK
LIGHT & AIR (COAL HATCH AT SIDES)
PROM DECK
UPPER DECK
BUNKER
LIGHT & AIR
SMOKING ROOM
LIGHT & AIR
STM TO WHISTLE & SIREN
MAIN STM
AUX STM
MAIN STEAM
FORCED DRAUGHT FANS
MAIN STM
PROMDE DECK
GALLEY
UPPER DECK
COAL BUNKER AT SIDES
PLAN OF HOLD
BUNKER
BUNKER
AIR LOCK
MAIN STEAM
AUXILIARY STEAM
AUXILIARY STEAM
MAIN STEAM
MAIN STEAM
STEAM TO WHISTLE
AUXILIARY STEAM
AUXILIARY STEAM
MAIN STEAM
GALLEY
COAL HATCH
VENT
AIR TRUNK
FORCED DRAUGHT FANS
FORCED DRAUGHT FANS
AIR TRUNK
VENT
COAL HATCH
PLAN AT UPPER DECK
STARRD
COALING PASSAGE
PORT
PORT
COALING PASSAGE
AUX STEAM
MAIN STEAM
STARRD
BUNKER
BUNKER

Plan and Elevation.

Cross Sections.

FIG. 124.—Arrangement of Boilers.

ADMIRALTY TESTS

The Admiralty trials between the reciprocating-engined ship *Topaze*, of 3000 tons displacement with 9000 indicated horse-power, and a similar ship, the *Amethyst*, fitted with Parsons' turbines, show clearly that the trials of the ships with reciprocating engines proved that the utmost that could be done with any degree of reliability was 22.34 knots; the *Amethyst*, for the same boiler power, easily steamed at 23.63 knots—an increase in speed of 1.29 mile per hour. But when it is noted that this gain was realised with easier steaming of the boilers, with the same weight of machinery, with no vibration of the ship—which enormously assists towards accuracy of gun-fire—and with quite 10 per cent. less coal per hour, and a correspondingly greater radius of action, the superiority of the turbine will at once be appreciated. The absence of reciprocating parts reduces possibilities of wear and tear. The height required for the turbine machinery is 20 inches less, so that it can be more easily housed under a protective deck. The air pressure in the stokehold was ½ inch less, so that there was, as a result, less stress on the boilers. The manœuvring capabilities of the turbine cruiser proved quite as satisfactory as the reciprocating-engine ships. The time required for stopping from full speed ahead, or from starting from dead stop, ranged from 7½ to 20 seconds, and only a few minutes was required to increase the ship's speed from 10 knots to 22 knots, so that the tactical advantage of the turbine need not be doubted. Economy is the one great element proved by the exhaustive and very carefully conducted trials of all four ships. At low power for 10 knots speed the water consumption was about 23 per cent. higher than in the reciprocating-engine ship. This excess, however, will be very materially reduced when the exhaust steam from the auxiliary engines on board the *Amethyst* is passed into the low-pressure turbine receiver instead of into the condenser—a practice carried out in the other ships. At 14 knots the conditions are, so far as economy is concerned, more equal; but when the speed was increased to 18 knots it was found that the consumption on board the *Amethyst* was something like 20 per cent. less, at 20 knots it was nearly 30 per cent. less, and at the higher speed the improvement was still greater. The influence of this economy on the radius of action is very marked; for instance, the turbine-propelled ship could, with her 750 tons of coal on board, steam 3160 sea miles at 20 knots, as compared with 2140 miles by the cruisers fitted with the ordinary machinery.

The following two comparative tables supplied by the Parsons Marine Turbine Company, and originally compiled from *Engineering*, give the performances at a glance:—

RESULTS OF STEAM TRIALS OF H.M.S. *AMETHYST* WITH PARSONS' STEAM TURBINES.

Date of trial		October 19 and 20	October 24 and 25	October 31 and November 1	November 4	November 8	November 16
Duration of trial		24 hours	24 hours	30 hours	8 hours	4 hours	4 hours
Draught of water (mean)		14 ft. 7 in.	14 ft. 7 in.	14 ft. 6 in.	14 ft. 8 in.	14 ft. 7 in.	14 ft. 6 in.
Speed of ship . . . . knots		10	14.062	18.186	20.6	23.06	23.63
Air pressure in stokeholds		0.2 in.	0.3 in.	0.45 in.	0.46 in.	1.7 in.	1.0 in.
Steam pressure in boilers		259 lbs.	263 lbs.	246 lbs.	255.2 lbs.	243.7 lbs.	260.6 lbs.
Steam pressure in receivers	Cruising H.-P.	94 ,,	216 ,,	..	..	..	..
	,, I.-P.	19 ,,	61.2 ,,	137.5 lbs.	190.6 lbs.	..	..
	Main H.-P.	2.7 ,,	18 ,,	53.7 ,,	75.6 ,,	158.3 lbs.	174.3 lbs.
	,, star. L.-P.	Vac. 21.7 in.	Vac. 10.8 in.	1.3 ,,	6.1 ,,	23.5 ,,	27.3 ,,
	,, port L.-P.	,, 19.9 ,,	,, 11.8 ,,	Vac. 1.3 in.	4.8 ,,	24.0 ,,	27.3 ,,
Vacuum in condensers	Starboard	26 in.	27 in.	26.6 ,,	27.8 in.	26.9 in.	26.5 in.
	Port	26.7 ,,	26 ,,	27.6 ,,	27.8 ,,	27.0 ,,	27.4 ,,
Revolutions	Centre	167.2	237.4	319.8	361.1	436	449.4
	Starboard	198.2	289.7	391.6	450.8	488.8	484
	Port	204.2	290.5	348.1	402.1	492.9	499
Consumption of water per hour		26,260 lbs.	44,090 lbs.	76,493 lbs.	100,606 lbs.	176,845 lbs.	190,525 lbs.
,, of coal per hour		2,893 ,,	4,725 ,,	8,372 ,,	10,937 ,,	24,035 ,,	24,412 ,,

RESULTS OF STEAM TRIALS OF H.M.S. *TOPAZE* WITH RECIPROCATING ENGINES.

Date of trial		August 1 and 2, 1904		August 2 and 3, 1904		July 12 and 13, 1904		August 7 and 8, 1904		August 10, 1904		July 28, 1904		August 13, 1904	
Nature of trial		24 hours at 10 knots		24 hours at 14 knots		30 hours at 18 knots		30 hours at 18 knots		8 hours at 20 knots		4 hours at full power		4 hours at 21¾ knots	
Speed of vessel . . . knots		10.058		14.08		18.1		18.069		20.063		22.103		21.826	
Steam pressure in boilers, lbs. per square inch		200		198		240		250		250		271		276	
Number of boilers in use . . .		4		6		8		8		10		10		10	
Air pressure in boiler rooms inches		0.2		0.28		1.19		0.87		0.83		1.8		2.04	
Vacuum	Starboard . inches	25.7		26.0		24.8		25.7		25.2		24.0		25.3	
	Port . . inches	25.3		25.0		24.0		24.8		24.4		24.0		23.8	
Revolutions	Starboard . . .	107.5		150.7		198.6		195.7		219.6		245.6		242.8	
	Port	106.5		150.3		196.8		195.7		219.2		245.5		243.8	
	Mean . . .	107.0		150.5		197.7		195.7		219.4		245.55		243.3	
		Starboard	Port	Starboard	Port	Starboard	Port	Starboard	Port	Starboard	Port	Starboard	Port	Starboard	Port
Mean pressure in receivers .	High . . lbs.	75	74	142	150	192	190	188	190	216	214	244	245	240	237
	Intermediate lbs.	13.6	13.9	39	46	59	60	59	61	74	76	89.6	94.4	89	96.5
	Low . . lbs.	3.6 in. vac.	5.2 in. vac.	2.8	4.2	12	13.8	8.7	10.6	14	15	22.2	23.1	22.5	23.9
Mean pressure in cylinders .	High . . lbs.	20.82	20.88	38.57	34.63	74	62	64.6	61.8	80	80	115	111	102.6	94.5
	Intermediate lbs.	6.94	7.0	15.57	15.15	26.1	28.4	25.7	27.3	34.2	36.6	44.5	47.2	44	49.9
	Low forward lbs.	6.34	6.07	9.25	10.36	13.8	15.2	13.29	15.04	16.7	17.25	20.1	21.5	20.7	22.84
	Low aft . lbs.	5.69	5.82	8.99	9.75	13.8	15.5	13.55	15.37	16.61	17.35	21.5	22.7	21.46	23.6
Mean indicated horse-power .	High . . .	125	125	326	292	821	684	706	678	983	982	1585	1534	1395	1292
	Intermediate .	106	105	331	321	733	790	735	755	1058	1132	1541	1637	1508	1716
	Low forward .	116	110	237	265	466	511	441	501	623	644	841	897	853	946
	Low aft . .	104	106	230	249	467	521	449	511	620	647	897	946	885	978
Indicated horse-power . . .		897		2251		4493		4776		6689		9868		9573	
Consumption of coal per hour . lbs.		2296		4640		10,484		10,900		15,451		26,150		27,700	
Consumption of coal per indicated horse-power per hour . . lbs.		2.56		2.06		2.3		2.28		2.31		2.65		2.89	
Consumption of water per hour per indicated horse-power . . lbs.		23.74		18.77		19.0		18.95		20.07		20.18		21.93	
Consumption of water per hour lbs.		21,294		42,260		94,867		90,500		134,248		199,140		209,950	

The steam turbine marine engine is not a very great advance upon the reciprocating engine, so far as it has gone to this date. In the first place, it does not reduce the vast amount of steam accessories, but rather increases them, as a better vacuum is necessary. There is also the high-speed screw difficulty. Their chief advantages are obtained in high-speed high-class vessels. The merchant steamer and tramp must still adhere to the old machinery which, working a vessel at 10 to 12 knots, cannot as yet be surpassed for the purpose. It runs economically, requires little attention, and is tolerably durable.

The turbine steamer is still in the hands of the few. In time it will receive the attention of the many engineers, and no doubt will become much simpler and offer many advantages for all classes of steamers. The process of development is very slow in engineering matters up to the stage where some enterprising capitalists enter the field and establish the invention as a practical working thing on a large scale—probably twenty years after the actual invention of the subject. The common crowd then rush in, in the hope of participating in the profits of the new manufacture. In this they may be disappointed, but they do some good by increasing the number of engineers interested in the subject, and out of it all some substantial progress is made.

In the case of steam turbines, however, the initial expenses in setting up a factory are very great. Even the introduction of the manufacture into existing engineering works has been too great an undertaking for many. Hence, although the turbine in its practicable shape is quite old, there are up till now but few makers.

INTERNAL COMBUSTION MARINE ENGINES

This engine is really the marine engine of the future. The energy of the fuel must be in the future obtained and applied in a far more direct method than by steam. With all the marvellous knowledge of thermodynamics, heat, and entropy of the present day, it is only more obvious that steam cannot be better utilised than it is at present.

The scientific knowledge of steam only leads to further additions to an already too numerous class of auxiliary apparatus. This is always a retrograde effect: true progressive invention simplifies and reduces complications.

The oil engines and producer gas engines convert the energy of fuel directly into mechanical power by the simplest means, and now bid fair to receive serious attention from shipowners and shipbuilders.

We have already, in Volumes II. and III., referred to internal combustion engines for marine purposes. Some further references will now be introduced as showing the trend of progress.

Fig. 125 shows three sets of Thornycroft's oil engines for marine purposes. On the right hand the larger size is a 4-cylinder engine, developing 75 indicated horse-power at 300 revolutions per minute. One of these sets is being fitted into a harbour service vessel for the British Admiralty. Standing in front of this is the air compressor—a small petrol engine and air pump for the starting reservoir. The second size is an 8-inch by 8-inch petrol motor, developing 100 horse-power at 800 revolutions per minute. This is also designed to work with paraffin at a slightly reduced power.

The small size is a 4½-inch by 5-inch motor, for launch and car work, developing about 30 horse-power at 1000 revolutions per minute. Engines for petrol have been designed for boats up to about 200 horse-power. But for the reasons already gone into—first cost, maintenance, running costs, and danger from explosion or fire—a preference is given to paraffin engines, or, better still, to suction gas producer engines. Messrs. Thornycroft are the only marine engineers who have practically taken the matter in hand, and from Mr. Thornycroft's paper to the Institution of Naval Architects we gather the following valuable views and information. The paper should be consulted by all interested in the subject. The engines considered are the three classes: petrol, paraffin, and gas producer. The petrol is carburetted, the paraffin vaporised, and the solid fuel in the producer gasified.

There is a greater variety of engines using oil, as paraffin, chiefly distinguished by the form of vaporiser used.

The stationary oil engine has been made very perfect for work where there are no very rapid or great changes of load, but for marine purposes, where a considerable amount of variation takes place in manœuvring, the problem becomes much more difficult. Most of the engines work on the well-known Otto cycle, and the variations occur in the different methods of introducing the fuel and vaporising it. In the case of the Priestman and Griffen, two of the earliest, the fuel is sprayed by air pressure into a vaporiser heated by the exhaust products, and then taken into the cylinder on the suction stroke. In the Vosper and Roots engines, it is either pumped or measured into a vaporiser without being sprayed.

In the Hornsby, the oil is pumped directly into an extension of the cylinder, which is maintained at a high temperature, and the air is introduced separately. This method has the advantage of great simplicity, as no igniting device is required, as the heat of this chamber is sufficient to ignite the charge on compression; but it is only possible to work with a very low compression, to avoid premature ignition, and therefore the type of engine is necessarily a heavy one.

The Diesel engine, which has as yet been only used in one or two cases for marine purposes, is a most interesting type. It works on the 4-stroke cycle, but sprays the oil into the cylinder by means of compressed air at the end of the compression stroke; the compression being so high (viz. about 500 lbs.), that when the oil is sprayed it at once ignites, due to the heat and compression. The temperature of compression being about 1000° Fahr., this itself would not ignite the oil, but, combined with the pressure, ignition is certain and combustion complete. It has been fully described in Volume II. The engine is necessarily heavy, to withstand the high pressures running to about 10 horse-power per ton.

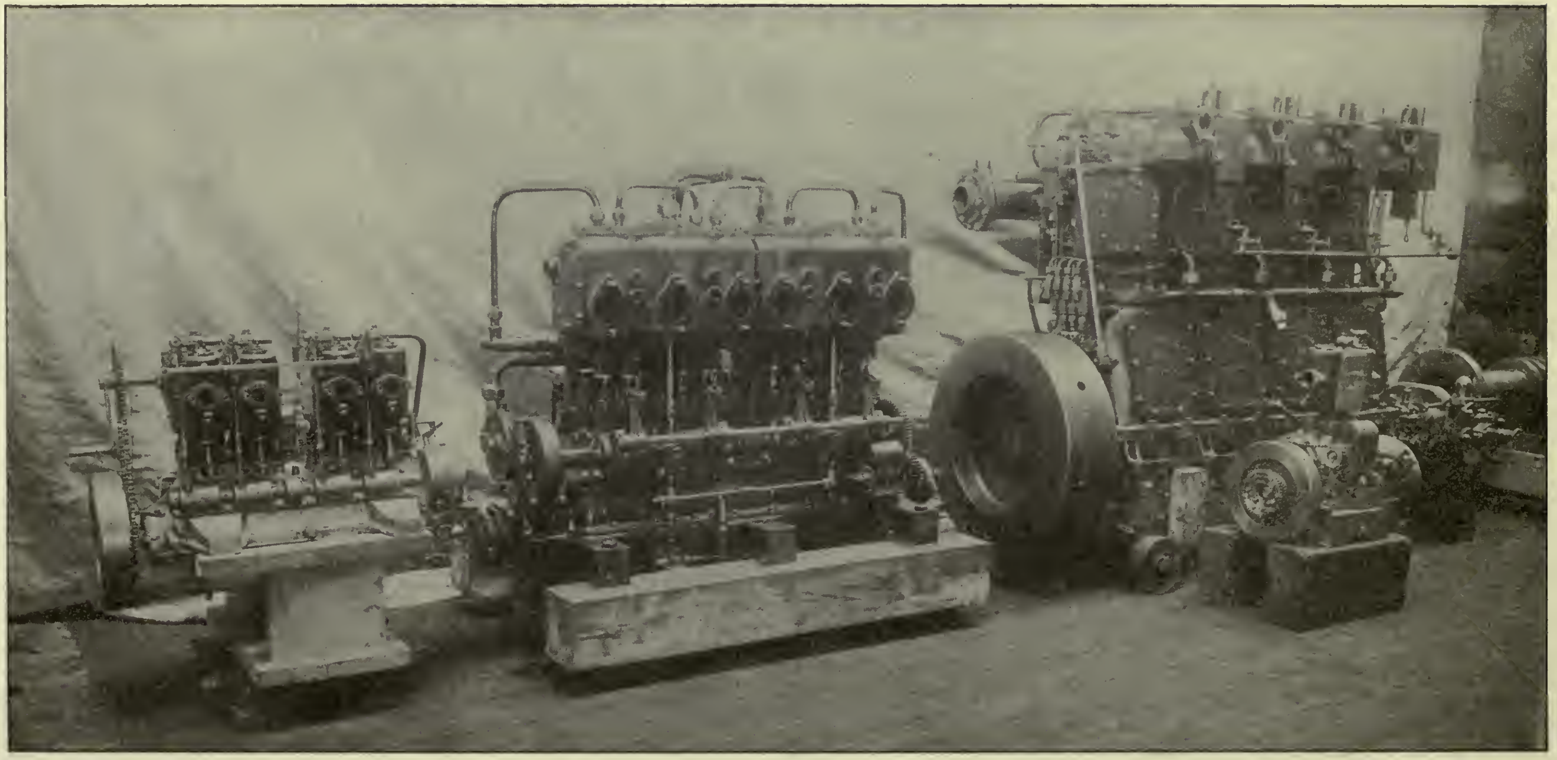


FIG. 125.—Group of Internal Combustion Marine Engines.

The Strickland engine works on the same principle, but at lower pressures—200 lbs.; it therefore has to use an igniter. It is a 2-cycle engine.

This Strickland type of engine offers some advantages, as it does not require to be so heavy. The Ackroyd engine could be used in the same way. It gets rid of the vaporiser, and only requires spraying of the oil into the compressed air. The third type is bound to prevail in time for heavy marine engine work. The producer is quite easily adapted to marine work, but the shipping people require educating up to its use. Each is waiting upon the other to take the first step, but in the end it must come to gas producers and gas engines.

The first type of engine is necessarily the lightest, as there is no vaporiser or producer, the fuel being vaporised by the simple expedient of sucking the right amount of fuel in with the air to the cylinder. Engines of this class are being made to weigh not more than 10 lbs. or 12 lbs. per brake horse-power. Comparing this figure with that of the modern torpedo boats or destroyers, which is 50 lbs. per indicated horse-power, it is evident that the naval architect has great possibilities with this type of engine. There is every prospect that engines of the second class will be built, including the vaporiser, for not more than 25 lbs. per brake horse-power for moderate sizes. The engine of the third class should not be heavier, but of course there must be added the weight of the producer.

Starting and Reversing.—The smaller types of engines for launches are very easily handled, it being possible to start them up by a few turns of the engine; but when the size gets too great to be man-handled, other means of starting have to be devised. In the large engines used in the submarines the engine is used in conjunction with electro-motors and dynamos, so that the motor can be used for starting up the engine.

In the case of the first and third classes, the starting is not very difficult, as the engine can be turned slowly with a suitable turning gear, and then, the cylinder being full of an explosive charge, they can be fired electrically at the right time, and the impulse is sufficient to carry the engine round for several revolutions and set it in operation.

In the case of the second class this is not practicable, and it is necessary to have a reservoir of compressed air or gas of sufficient volume to give the engine several turns working as a pressure engine: this, of course, necessitates additional valves for the purpose. In smaller motors it is possible to reverse either by a reversing screw, or in some instances it is accomplished by stopping the engine, and by having suitable cams for operating the valves and starting the engine in the reverse direction by hand; but this has not been found very satisfactory, and the best practice seems to be to fit the engine with a suitable reversing gear and clutches for throwing it in and out of gear. It is at present unknown to what sizes these reversing gears can be successfully built, but recent improvements in clutches made by Professor Hele-Shaw go to show that there should be no great mechanical difficulties in producing them up to several thousand horse-power.

A comparison of the weights and space occupied by comparatively low-powered engines of the first class fitted to launches in the place of steam engines and boilers of the same power shows very greatly in their favour; but when petrol is used as fuel, it will be found more expensive than coal to do the same work. On the other hand, as the engines are practically automatic in action, and can be started at once (requiring no preparation like a steam boiler), an engine-driver can usually be dispensed with, and, as the steersman can do all the work of controlling the vessel, it will frequently be found cheaper to run with this class of engine than with steam.

While there is very little danger from fire with properly constructed engines fitted with electrical ignition, and using spirit or oil of a low flash point in open boats, the risk must not be disregarded where they are fitted in a closed engine-room below decks.

Captain de Boulay has devised an arrangement by which only a small quantity of fuel is kept in the engine-room in a small tank, any leakage draining directly overboard. The main supply is stored in a tank in a specially bulkheaded compartment, which also drains overboard; and in some cases the sea is allowed to flow into it and around the tank, thereby avoiding any possibility of the leakage of oil into the bilge of the vessel.

With engines of the second class, using oils having a flash point of above 75° F., there is practically no danger from fire, and when the engine will work with less than 1 lb. of oil per horse-power hour the cost of working will, as a rule, be found less than that with the equivalent steam machinery; but, as yet, there has always been the disadvantage of an objectionable exhaust.

The Diesel engine costs only one-tenth of a penny per hour, as it works with unrefined oils, which can be bought for twopence per gallon, and uses less than ½ lb. of oil per horse-power hour. Only the most economical steam engines, supplied with coal at not more than 10s. per ton, can equal this performance.

It is well known that gas engines of even small powers, supplied with producer gas, give considerably more power per pound of fuel than could be obtained with a steam engine and boiler, and when large plants are used a given quantity of fuel will produce about four times the power obtainable with ordinary steam engines.

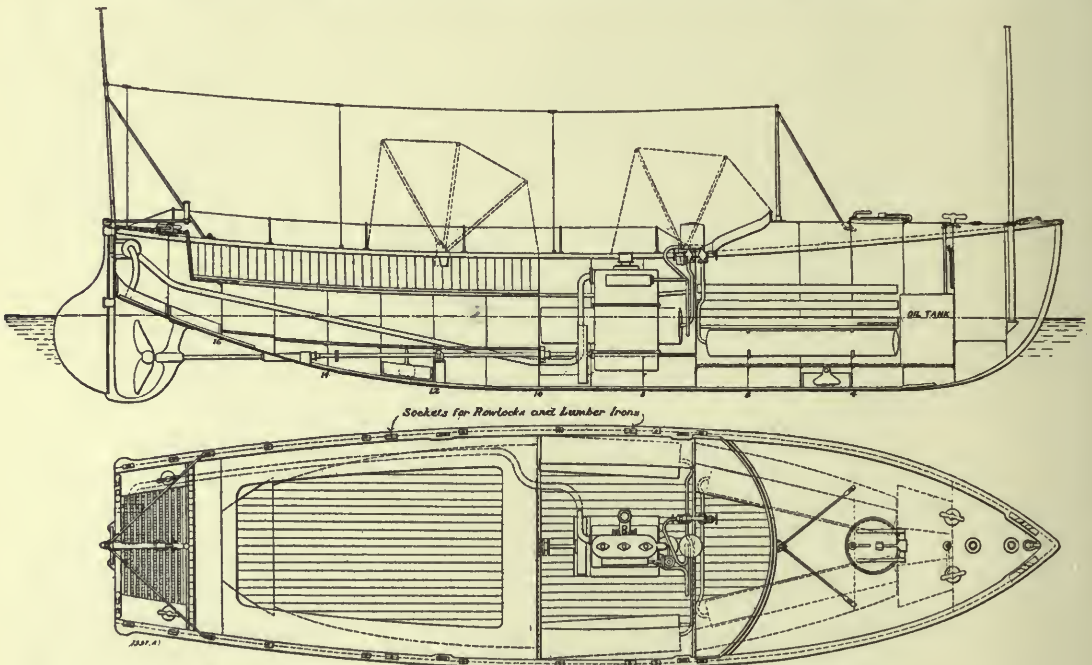


FIG. 126.—27-Foot Cutter fitted with Reversing Petroleum Motor.

Fig. 126 shows the space occupied in a 27-feet naval cutter by a reversing engine of the second class (paraffin), taking just half the space occupied by the regulation steam engine and boiler. Fig. 127 shows the relative space occupied by the machinery of 6000 indicated horse-power of a torpedo-boat destroyer fitted with the usual machinery, and an oil engine of the second class working on a 4-cycle at the same piston speed as the steam engine.

In order to still further compare the different types of internal combustion marine engines, a design for a tramp vessel of 1100 horse-power, fitted with a gas producer and gas marine engine, is given in Fig. 128, attached to a screw propeller, and in Fig. 129 attached to two of the author's jet propellers.

The gas producer plant is separately shown in Fig. 130, a sectional elevation and plane. There are four gas producers, any three equal to the full demands of the engine; two jet scrubbers, two coolers, and one reservoir. Referring to Fig. 130, G, G, G, G are the producers; C, C, the coolers; and W, scrubbers; H, the reservoir; *a*, *b*, *c*, *d* are controlling valves; *e*, *f*, steam jet blowers; and *g*, the bypass to the chimney.

Anthracite coal is preferable, as it requires less cleansing of the gas it produces; but bituminous coal can also be used. A plentiful supply of cold water properly applied in the coolers will remove the objectionable tar and dust from the gases, and this can always be obtained by simple circulating pumps.

Fig. 128 shows the screw-propelled vessel with one set of 4-cylinder 2-cycle engines, working by suction on the exhaust, as previously explained in Volume III.

The producer plant is the same as that just described. This engine and propeller would be controlled by the double friction clutch K, which can be used both for slowing down and for reversing. The Hele-Shaw clutch used for large powers is shown in Fig. 131, giving a very clear illustration of its simple construction and working.

Fig. 129 is an illustration for comparison with the other, and fitted with two sets of double-cylinder engines, two pumps, and two jet propellers, the one set discharging to port and the other to starboard.

The whole subject of marine gas engines is one as yet confined to the stage of proposals and suggestions; but there is ample experience and reliable results to be found in land engine installations to clearly warrant the recommendation of this prime mover to shipbuilders and owners for cargo ships. It can be used either with the screw propeller and reversing clutch, or the jet propeller; in both cases the controlling of the vessel is all that can be desired.

Internal combustion engines are

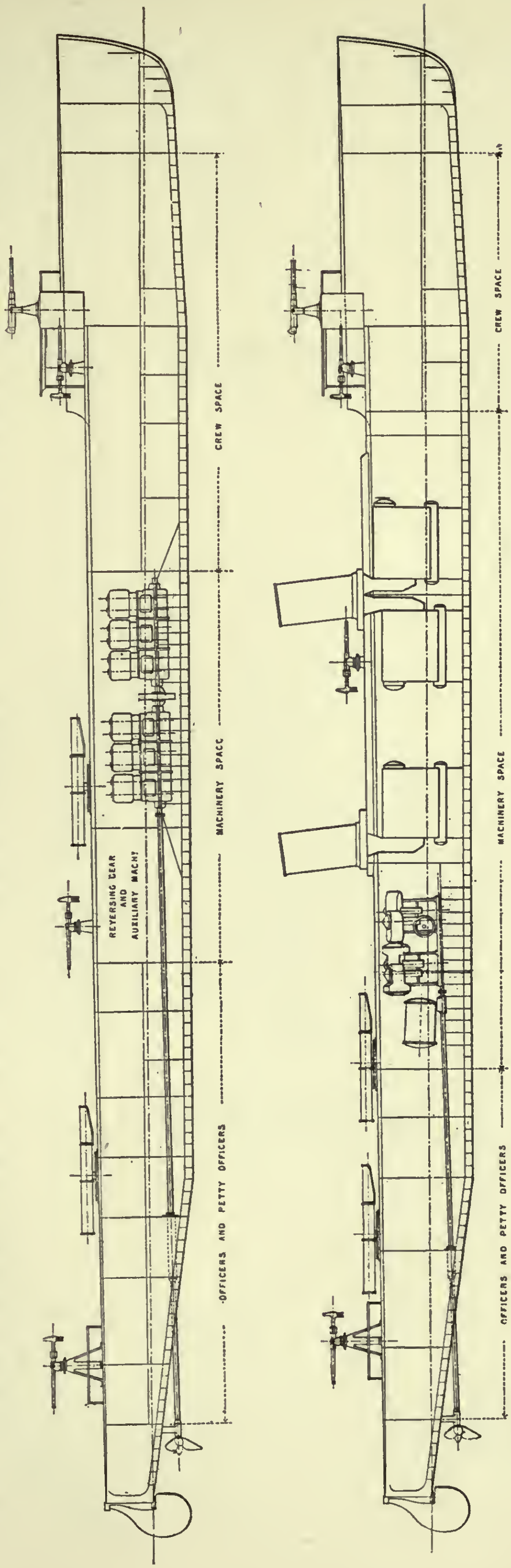

CREW SPACE
MACHINERY SPACE
REVERSING GEAR AND AUXILIARY MACH'Y
OFFICERS AND PETTY OFFICERS
CREW SPACE
MACHINERY SPACE
OFFICERS AND PETTY OFFICERS

FIG. 127.—Relative Space occupied by Steam and Internal Combustion Engines for a Destroyer.

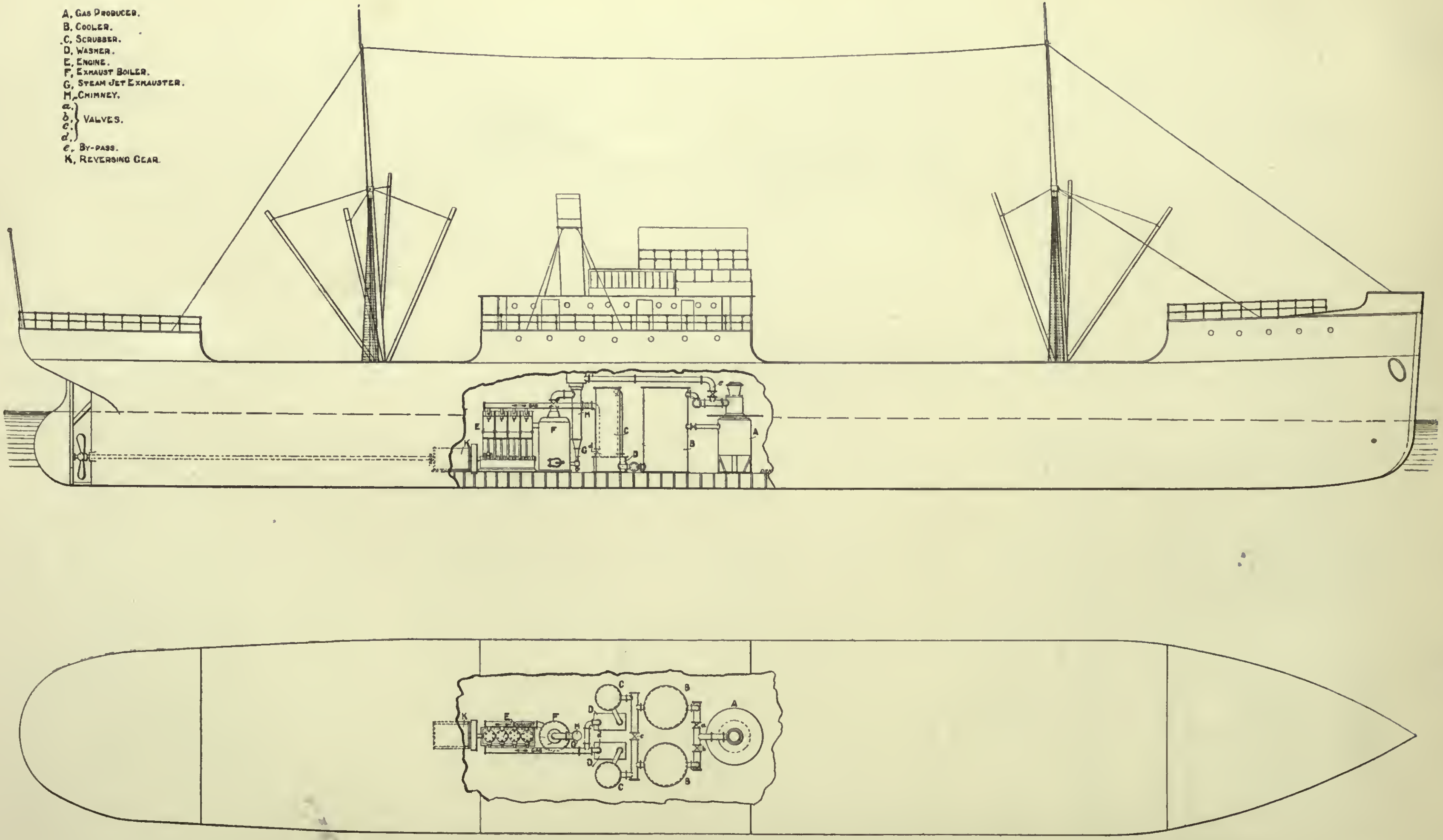

A, Gas Producer.
B, Cooler.
C, Scrubber.
D, Washer.
E, Engine.
F, Exhaust Boiler.
G, Steam Jet Exhauster.
H, Chimney.
a, b, c, d, Valves.
e, By-pass.
K, Reversing Gear.

Fig. 128.—Gas-driven Cargo Vessel with Screw Propeller.
Length, 335 feet ; Breadth, 48 feet ; Draught, 24 feet 3 inches.

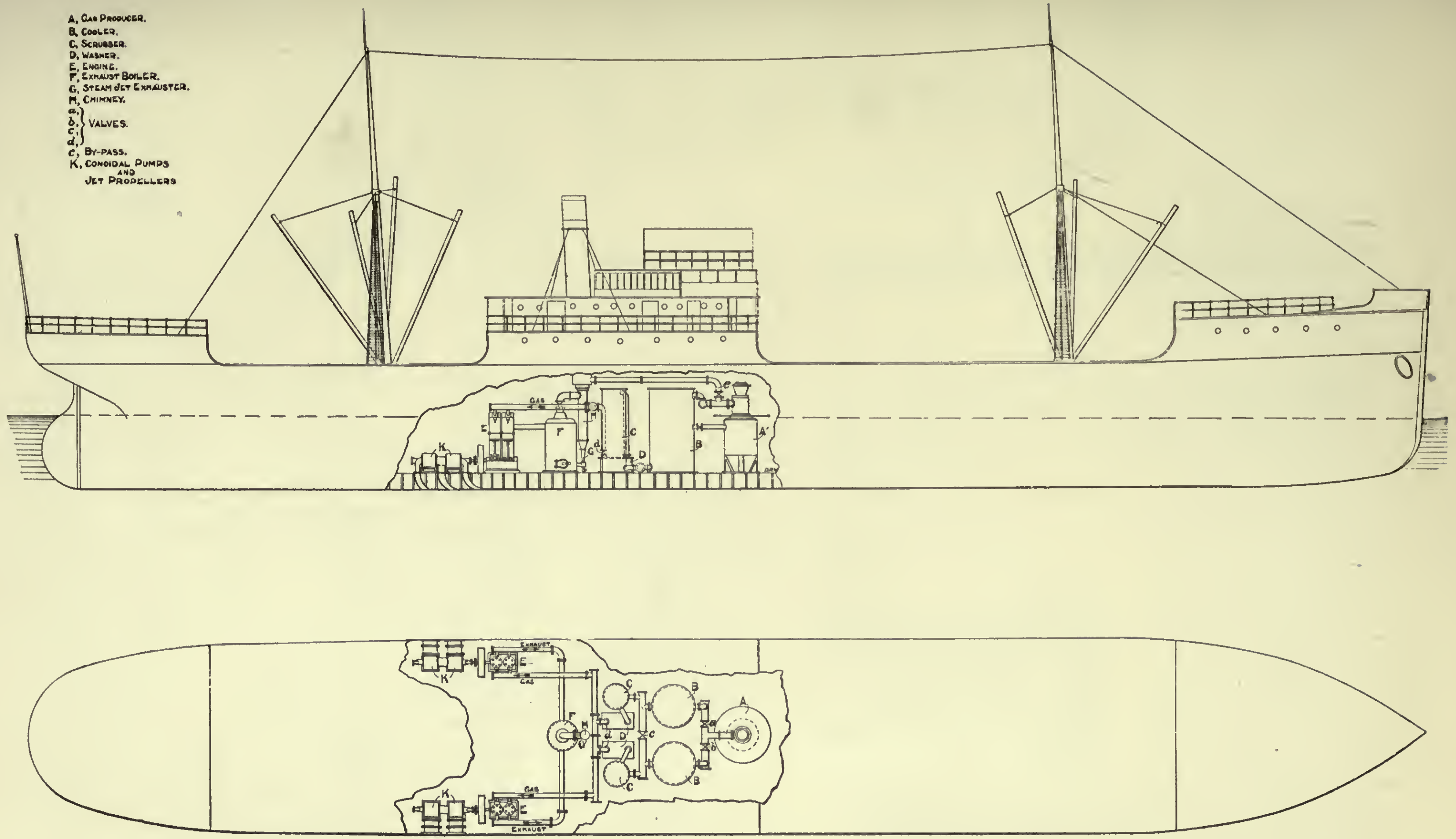

A, Gas Producer.
B, Cooler.
C, Scrubber.
D, Washer.
E, Engine.
F, Exhaust Boiler.
G, Steam Jet Exhauster.
H, Chimney.
a, b, c, d, Valves.
c, By-pass.
K, Conoidal Pumps and Jet Propellers
Gas
Exhaust
A
A'
B
C
D
E
F
G
H
K
a
b
c
d
e

FIG. 129.—Gas-driven Cargo Vessel with Jet Propellers.
Length, 335 feet ; Breadth, 48 feet ; Draught, 24 feet 3 inches.

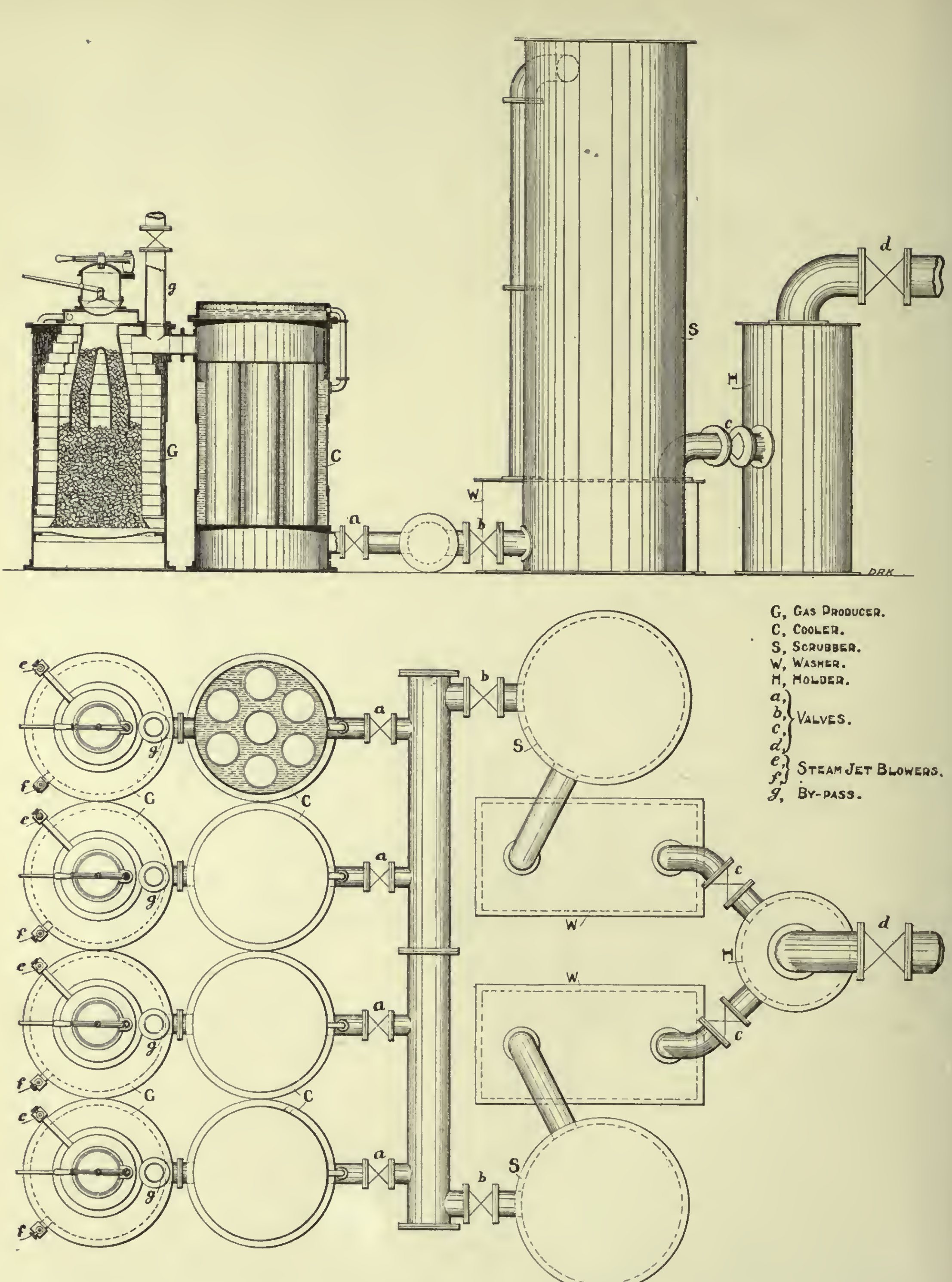

g
G
C
S
W
H
a
b
c
d
DRK
e
f
G, Gas Producer.
C, Cooler.
S, Scrubber.
W, Washer.
H, Holder.
a, b, c, d, Valves.
e, f, Steam Jet Blowers.
g, By-pass.

Fig. 130.—Sectional Elevation and Plan of 1100 Brake Horse-Power Marine Bituminous Coal Gas Producing Plant.

specially suitable for auxiliary powers on sailing vessels, more especially with the hydraulic jet propeller. Pursuing the subject of jet propellers compared with other types of propellers, the theoretical results have been already discussed.

The practical efficiency falls short of these theoretical results with all forms of propellers, due to many causes. In the case of the jet propellers tried, the chief sources of loss were three in number: first, at the inlet of the water; second, in the pump; and thirdly, in the jet. The losses at the inlet shall be referred to later on. In the torpedo boat referred to, the pump losses amounted to no less than 54 per cent., and the loss in the jet 30 per cent., their efficiency being respectively 0.46 and 0.7. Upon considering these figures, the efficiency of the jet propeller did not seem so hopeless, for the efficiency of centrifugal pumps was known in many cases to be much higher than 0.46, while a loss of 30 per cent. in a simple affair like a jet seemed capable of considerable reduction. In regard to the pump, inquiries were made among leading makers at home and abroad, and several firms were found prepared to make and supply pumps of 10 horse-power and upwards with an efficiency guaranteed not less than 80 per cent., thus placing the jet propeller in a much better position.

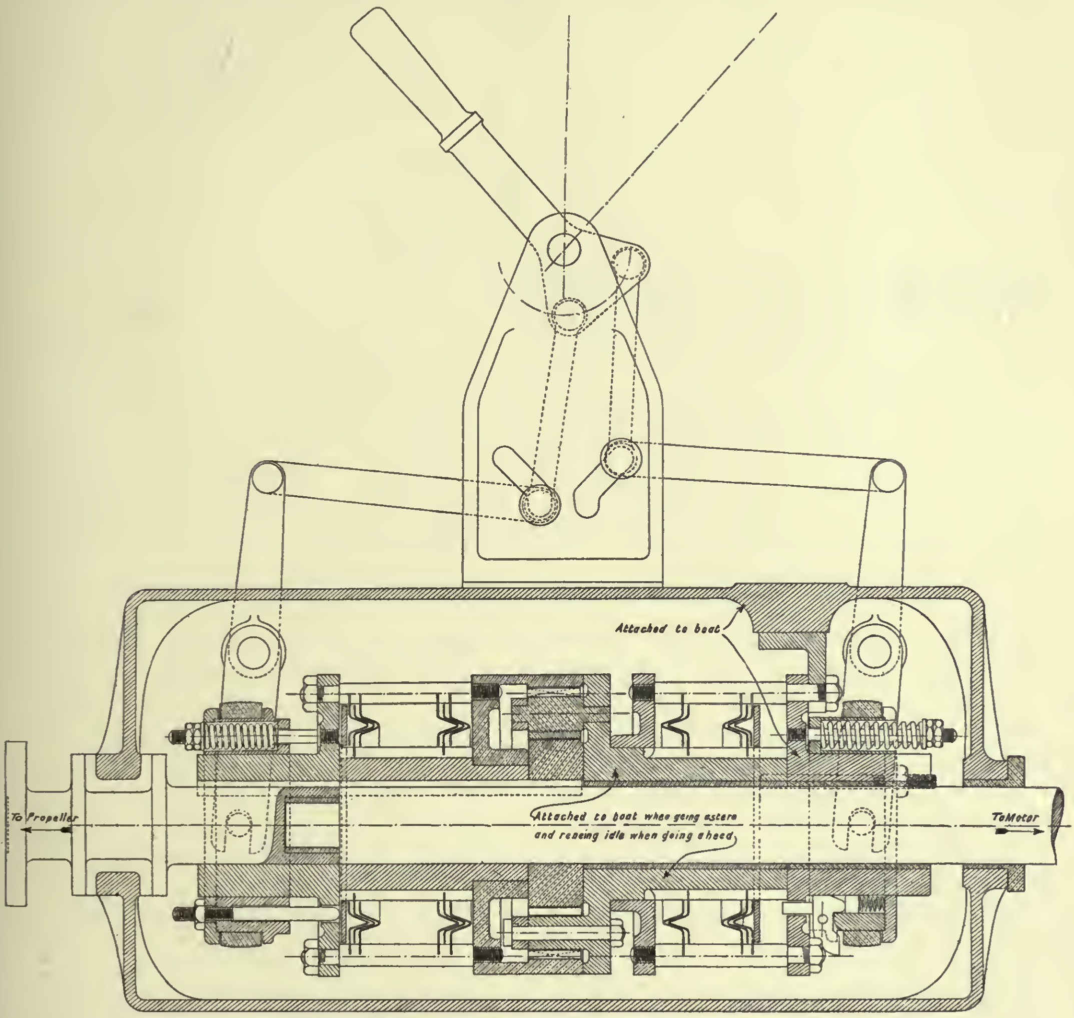

Attached to boat
To Propeller
Attached to boat when going astern and running idle when going ahead
To Motor

FIG. 131.—Hele-Shaw Reversing Marine Clutch.

The loss in the jet was not accounted for easily, so that a series of actual tests with various jets had to be undertaken to obtain the necessary information. The various jets were tested on a 12-feet to 16-feet head of water by a spring balance, as shown in Fig. 132. The jet was carried upon a flexible rubber tube connecting it to the supply pipe. The reaction t of the jet was measured in this way in lbs., and could be compared with the calculated reaction T, so that $\frac{t}{T}$ would give the jet efficiency.

In this way, efficiencies ranging from 0.65 to 0.90 were observed, the latter with a specially designed jet nozzle. No special reference need be made to the various jets tried, as the best one alone is of interest, and somewhat novel. This propeller jet has turbine guide-blades inserted in the discharge orifices, whereby the issuing water is accelerated in velocity and deviated in direction, and discharged in a number of thin broad jets, each equal in propelling power.

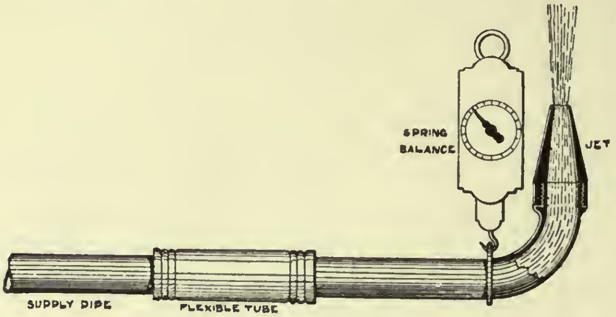


FIG. 132.—Testing Jets.

This form of propeller is shown in Fig. 133 in diagram. The sectional area of the pipe is four times that of the orifices, so that, if the velocity of the water at the orifice is 24 feet per second, the velocity in the pipe is only 6 feet per second. With this form of propeller, which is entirely new, an efficiency of 85 per cent. can easily be obtained in the jet: over 90 per cent. has been obtained. The comparison between the efficiencies formerly obtained with that now obtained with the jet propelled are—

1883.—Naval torpedo boat . pump = 0.46 jet = 0.7 = total = 0.322.
1904.—Experimental results . ,, = 0.80 ,, = 0.85 = ,, = 0.68.

These are not the highest efficiencies obtainable, but averages to be reasonably maintained in practice. Few screw propellers reach such a high efficiency.

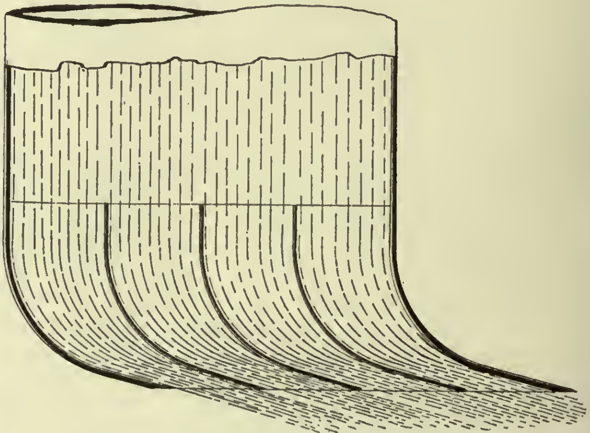


FIG. 133.—Kennedy's Patent Jet Propeller.

There are the losses at the intake of the water into the pumps. If the water entered a pipe in the vessel, with an opening facing forward, and flowed out of the pipe facing aft, it is evident that, if the vessel was under sail, the water would flow through the pipe, if there were no obstructions, with a velocity equal to that of the ship or vessel, but with no velocity relative to the water outside the ship. If now a pump is inserted in the pipe and the water given an impulse by the pump, the velocity of the water would be greater than that of the ship by the additional speed given by the pump. This additional speed is the true slip S, the velocity due to the speed of the vessel is = V, and the velocity of water discharge = V + S, as we had before. But the water in practice is not free to flow through the pump and pipes, hence V is always less than the speed of the vessel, and the deficiency is the loss. However, this loss, by properly designing the intake with easy bends and large area of inlet, is not more than 15 per cent.

It has been calculated that a vessel with a 20-feet draught and 40-feet beam, to be driven at 10 knots with a 1000 indicated horse-power engine, would require two jets, each with an orifice equal to a hole 32 inches in diameter, and four inlets of same size—not very great, compared with the vessel in dimensions.

In a small boat 20 feet long and 5 feet beam, with a total weight of 1 ton, a speed of 6½ miles per hour was obtained with a jet the orifices of which were equal in area to a hole in each side of the vessel equal to 2 inches in diameter.

In most vessels it is better to have a hydraulic turbine bladed propeller jet, fixed in each side of the vessel flush with the external skin of the vessel, and to keep them below the water line; and two pumps are used—one to work the port propeller, and the other to work the starboard propeller.

The propeller blades are of brass, fixed in a valve box screwed to the inside of the vessel, with the outer edges of the blades flush with the outside. A copper grating protects the inlets in the bottom.

The valves on the propellers can be operated by levers and chains from the deck, so that the vessel can be controlled without reference to the engineer.

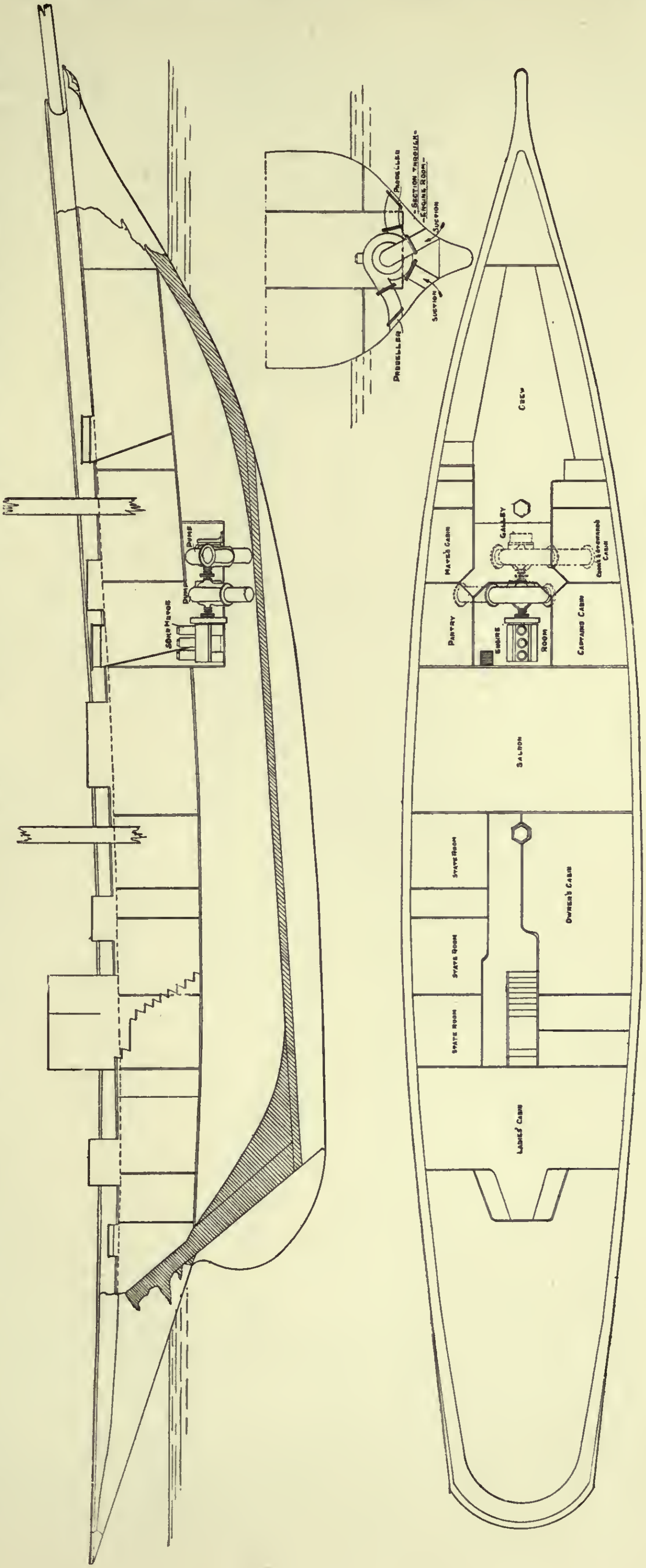

PROPELLER
SECTION THROUGH ENGINE ROOM
SUCTION
SUCTION
PROPELLER
PUMP
PUMP
50HP MOTOR
CREW
GALLEY
MATE'S CABIN
PANTRY
ENGINE ROOM
CAPTAIN'S CABIN
SALOON
STATE ROOM
STATE ROOM
STATE ROOM
OWNER'S CABIN
LADIES' CABIN

Fig. 134.—Fast Cruiser with Auxiliary Motor and Hydraulic Jet Propeller.

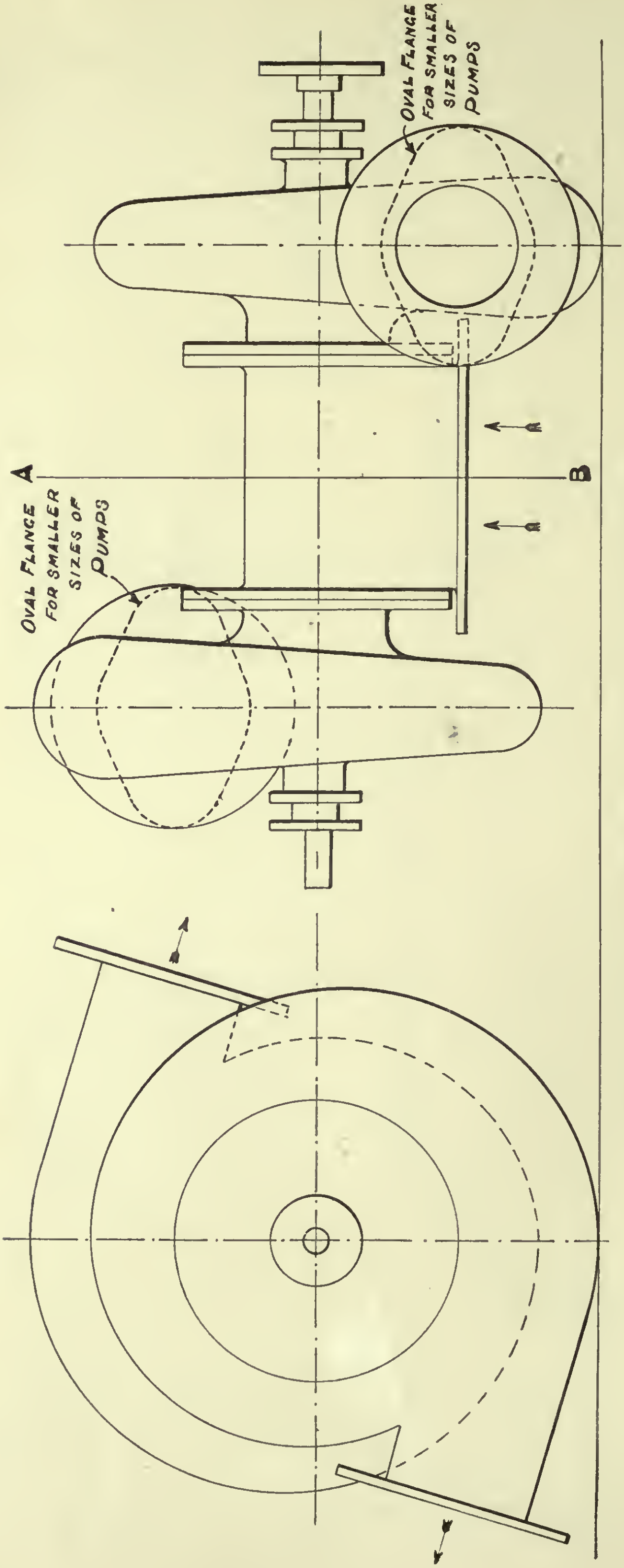

OVAL FLANGE FOR SMALLER SIZES OF PUMPS
OVAL FLANGE FOR SMALLER SIZES OF PUMPS
A
B

FIG. 135.—End View and Elevation of Double Pump for Jet Propeller.

In order to show the arrangement of pumps, engine, pipes, and valves, they have been drawn into a design of the schooner-rigged yacht *Clara* (see Fig. 134), which was illustrated in *The Yachtsman* (Supplement Design No. 27), 5th May 1904. The pumps have their shafts running fore and aft, direct-coupled to the engine shaft. The intake in the bottom consists of two 18-inch inlets, one each side of the keel, while the propeller orifices each have an area equal to a 10-inch diameter outlet.

The horse-power of the engine is 50 brake horse-power.

It will be observed that the structural alterations are not great. The engine, in any case, would require a compartment opening up to the upper deck.

The experimental work in connection with the jets and pumps has extended over two years. The results are now complete enough to enable propellers to be designed and made for all purposes and speeds, the only data required to be furnished being the thrust desired and the speed required of the vessel.

For smaller craft, one engine and a double pump have been designed to work the port and starboard propellers, the shaft of the pump being coupled to the engine shaft and running fore and aft the vessel. Figs. 135 and 136 show an end view, a side view, and a section between the two pumps on line A B. The suction is between the two pumps, and one half the water is thrown to one side, the other half to the other side of the vessel. The pumps are light in weight, small in size, and highly efficient.

MARINE GAS TURBINE

The gas turbine has made but little progress beyond that recorded in Volume II., but a combination of the internal combustion engine and gas turbine bids fair to become a practicable prime mover.

In all gas turbine proposals the question of compression, without which no gas engine can be economical, is a very important subject, and presents great difficulties. The only attempt at a practicable solution of these difficulties is that of the author's design, page 41, Volume II., a design which has been adopted in some turbines since introduced. In that type the compression is limited, and not efficient; but a turbine on these lines runs quietly and has no complications, requires no attention, so that, despite its low efficiency, it has much to recommend it otherwise.

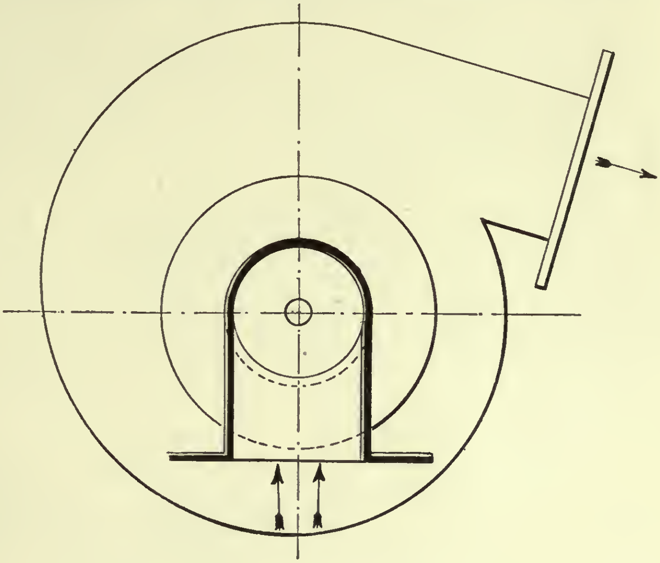


Fig. 136.—Section through A B.

Following up the subject of gas turbines, the author designed a combined turbine and engine. The internal combustion engine draws in a cylinder full of air and fuel, at atmospheric pressure very nearly. This is compressed and fired, and expands again to its former volume, driving the piston forward and doing work; but the expansion is not nearly great enough to reduce the pressure to near that of the atmosphere, and no satisfactory system of reducing it by doing work has been proposed hitherto.

The exhaust therefore escapes at a pressure varying between 30 to 50 lbs. per square inch, and red-hot. This is shown in the indicator diagram of all gas, oil, and petrol engines, and an example is shown in Fig. 137.

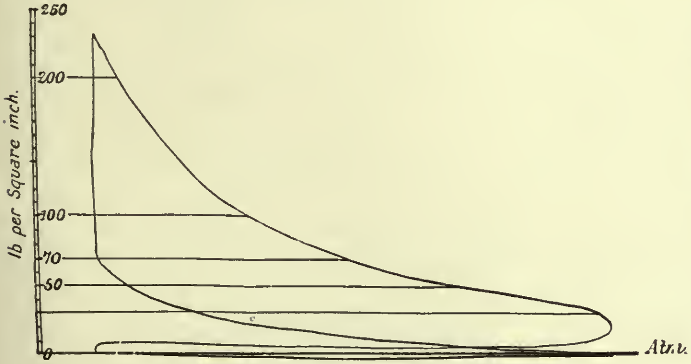


Fig. 137.—Indicator Diagram of Gas Engine.

The exhaust from a gas engine or oil engine will therefore drive a gas turbine with considerable power.

In order to realise this combination with the best effect, it is necessary to employ a type of engine which exhausts at the end of the stroke of the piston, for if the exhaust is made to pass through a valve by the piston driving it out, the heat is wasted. I therefore employ 2-cycle cylinders worked upon the Clerk cycle (see pages 50 and 51, Volume II.). Only, in order to increase the power developed in the turbine, I increase the size of the air and gas pump, and set the pump crank only slightly in advance of the working crank. By this means I compress into the combustion chamber a much greater volume of mixture of gases than the volume of the working cylinder, and consequently when the mixture is fired and expands in the working cylinder its pressure at the end of the stroke is very high. The piston uncovers ports at the end of the stroke, and the high-pressure gases pass into the turbine, and these are fully utilised.

The turbine wheel is geared to the engine crank shaft, so that both powers act together.

Referring to Fig. 138, this combined turbine and engine are shown in diagram. A is the pump cylinder, which draws in a mixture of fuel and air at atmospheric pressure; B is a pipe communicating with the inlet valve C of the working cylinder; D are the outlet ports for the exhaust from the working cylinder to the turbine through pipe E; S is the ignition plug.

Assuming the working piston to be at the outer end of its stroke, and the exhaust has all escaped into the turbine, the large piston has moved up some small distance, expelling a charge through C to displace the exhaust; both pistons then move upwards, the small one closing the exhaust ports. The charge in both cylinders is then compressed into the combustion space in the small cylinder; the large piston then starts on its downward stroke, and the charge in the small cylinder is fired. The expansion and exhaust then take place, and the high-pressure exhaust propels the turbine. This cycle is again and again repeated.

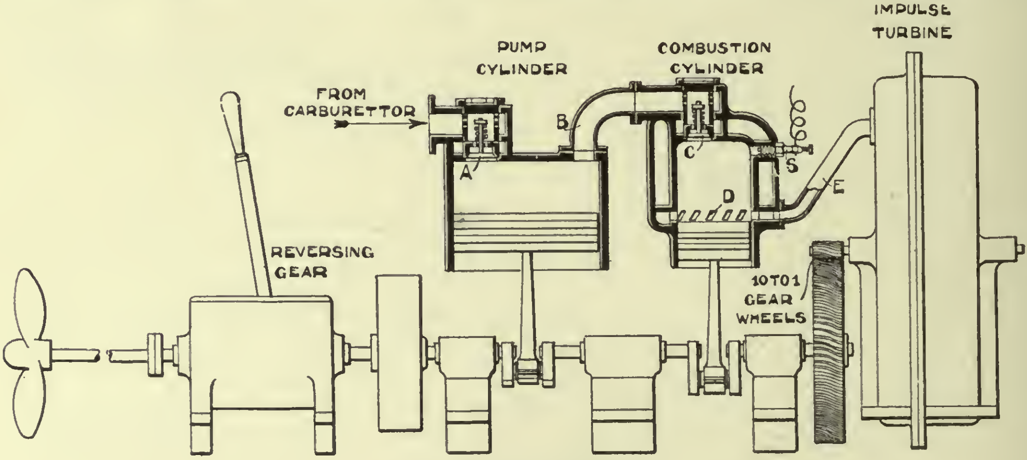


FIG. 138.—Gas Turbine.

The turbine may of course be used apart from the reciprocating engine, although utilising the exhaust from that engine.

The combination is useful even without the large pump, and may be applied to any engines, 2- or 4-cycle, to recover the power in the exhaust gases, instead of frittering it away in exhaust silencers.

This combination offers a solution of the compression difficulties with gas turbines, also the high temperature difficulties are to some extent overcome. The gases are compressed to a high degree, and in doing work on the out-stroke and also by the water jacket are reduced in temperature before entering the turbine.

MOTOR BOATS

If little progress has been made in adopting internal combustion engines on large vessels, that cannot be said of the small craft. Motor boats have come into great favour, and, as they become more and more adapted to the work, promise to completely displace the small steamboats.

In small boats, partially decked or open, petrol is the favourite fuel, and it has much to recommend it. Properly stored and with properly laid copper pipes, and ordinary precautions, it is quite safe.

Paraffin is cheaper and safer on the whole, but there seems a difficulty about the vaporisers, although in some boats recently launched it appears to work very satisfactorily.

Few small motors can compare with the little paraffin motor of Mr. George Seal of Hammersmith, varying in power from 1½ to 5 brake horse-power. They are made with two sizes of cylinder, 3-inch bore and 4-inch stroke, and 3½-inch bore and 5-inch stroke, speeds between 800 and 1000.

The essential peculiarity of the Seal motors, as will be seen from sectional Figs. 139 and 140, is that the cylinder A is inverted. The combustion chamber and its water jacket, as well as the water-jacketed valve passage A_1—which is common to both inlet and exhaust—are contained in the base casting. Actually the water jacketing is slightly deeper beneath the head than is shown, and cast open on each side of the base casting for removable panels P, P (Fig. 139). This system of construction enables the bowl-shaped crank case casting B to be removed bodily, with the upper halves of the crank shaft bearings, for inspection, etc., without disturbing any other part of the motor, as soon as the half-dozen nuts which unite A and B are slacked off. It also disposes of the problem of lubricating the brasses at either end of the connecting rod, besides affording piston lubrication on the splash system. The bulk of the oil, however, from the large lubricator C falls into the piston trunk, thus preventing to a great extent the over lubrication of the motor. The shaft bearings are lubricated from smaller lubricators C_1, between one of which and the larger lubricator will be seen a relief port RV, for any crank case compression that may occur. A compression cock RC is also fitted at the left-hand end of the combustion chamber.

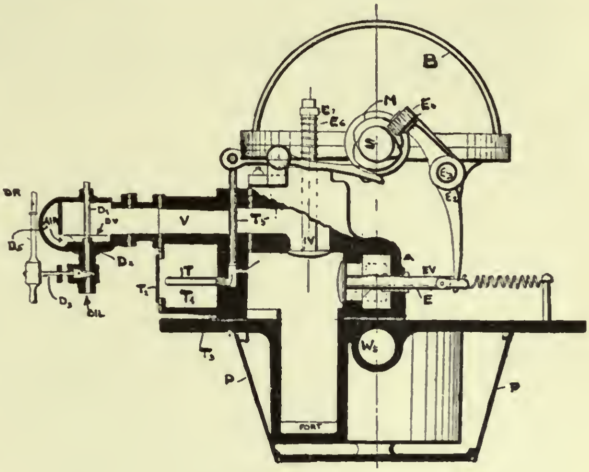


FIG. 139.—Seal Motor. Sectional End View.

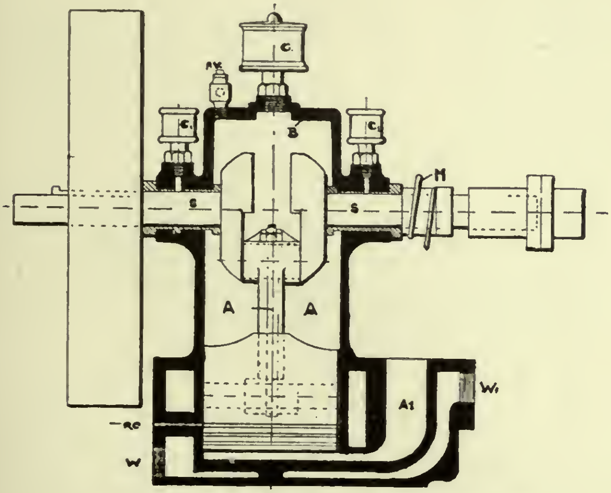


FIG. 140.—Seal Motor. Sectional Elevation.

The crank shaft S is carefully balanced, and carries a cam M, of somewhat uncommon type in motor construction, and of a compound function, which is much assisted by its helical shape. It operates the exhaust valve E through the rocking arm E_2. This is pivoted on a stud E_3, and carries on its upper arm a star gear E_4, engaging the cam M, while its lower arm engages the end of the valve stem E_1, to which is attached (by a shackle E_5) a strong spring E_6 in tension, attached at its other end to a chape or stud E_7, the tension of the spring keeping the valve normally closed. The only reason for the star gear being fitted is that it keeps the rocker in constant engagement with the cam.

The automatic inlet valve is IV, situated centrally in Fig. 139. Practically this is a non-return valve, that is to say, it has nothing to do with the correction of the mixture, as might be supposed from the presence of the primary inlet or air delivery valve DV, which regulates the due proportioning of the mixture. This valve is a flexible one, its disc being composed of a circular sheet of resilient metal, cut helically from its insertion in the spindle D_1, so as to form a flat spring. It rises more or less in exact response to the strength of the piston suction, which, though lasting for but a short period, is conveyed to it along the whole length of the vaporising passage V, when the non-return valve opens. The regulation of the air supply, and consequently its proportion in the mixture, is thus automatically effected at all speeds. With it is regulated the supply of the oil for each charge; for it will be noticed that the spindle D_1 is also formed as a needle valve, fitting closely in the mouth of the oil jet D_2. To this the oil is supplied from below by gravity feed, and is primarily regulated by the coned end of a threaded spindle D_3, rotated by the balanced lever R, mounted on the other end of D_3. The air is drawn from the induction pipe D_5, one end of which only is shown in Fig. 139, its remainder being continued round the other side of the motor and formed into a skirt round the exhaust pipe.

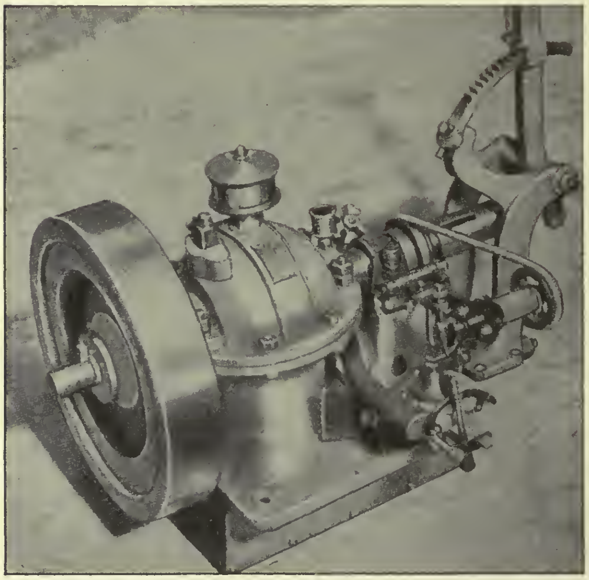


FIG. 141.—Seal Motor.

The oil being sprayed in a minute quantity upon the valve DV (and at high speeds partially through its turns), and mixed with the dry air also drawn in, enters the vaporiser casting V, which, as well as the ignition tube IT, is heated at starting by a blow-lamp, entering the heating chamber T_1 through a little hinged door T_2. The vaporising tube V is heated a fairly high temperature at first, but the induction period being extremely rapid, even the first few charges have no time to be overheated before being drawn into the combustion space. A rather ingenious baffling piece (not shown) is inserted in the vaporiser V in a tight fit, so that it will not be drawn against the stem of the valve IV. This consists of a gun-metal casting formed in two vertical discs, spaced an inch and a half apart upon a horizontal diaphragm, which is cast open, the mixture being thus perpetually turned at right angles; the diaphragm, of course, being considerably wider than the discs, and making the fit with the vaporising tube.

The Seal patent ignition tube, the essential quality of which is that it remains incandescent without requiring more than preliminary heating, consists of an ordinary tube of very close-grained iron, enclosed in an iron sleeve of considerably greater diameter. The space between tube and sleeve thus forms an intensely hot gas jacket, the gases entering the sleeve through small perforations in the walls of the inner tube, which is screwed into a little ignition chamber T_3, formed in the casting of the vaporiser and heating chamber V and T_1. This chamber is entered from the combustion space through the port T_4, and is completely filled (and the tube T thereby isolated from the charge) by the plunger spindle T_5, which is mounted as shown on one of the two short arms of a bell crank N, the long arm of which engages the cam M. Now, during the whole of the cycle, except for a short period at the end of the compression and beginning of the working stroke, the cam M merely engages this arm of the bell crank without depressing it, the plunger T_5 being normally held down by the action of a strong spring attached to the other short arm of the bell crank N and to a stud on the base casting. In Fig. 139, however, the cam M is shown at the ignition period, depressing one arm of N, and lifting T_5 to admit the compressed gases to the tube T, the combustion chamber of which is cooled thermally by water led directly from without the boat to the inlet W, and out again above the water line from the outlet W_1, on the top of the base plate—no pump of any kind being needed, as the whole of the water jacketing is well below the water line. The total weight of the 3 horse-power motor illustrated is barely 50 lbs. per horse-power, including weight of fly-wheel.

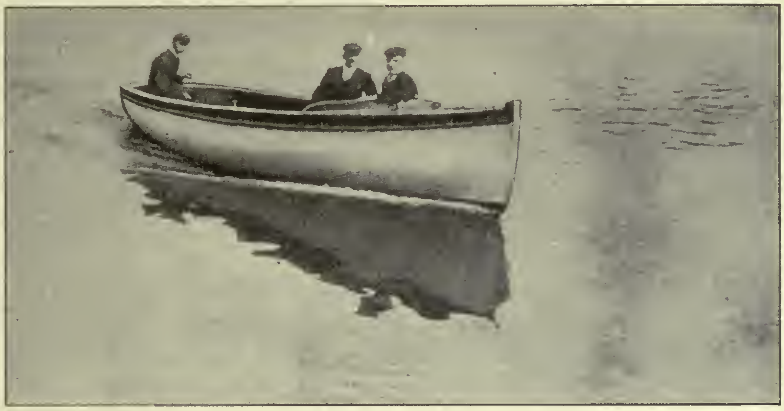


FIG. 142.—Motor Boat.

The engine may be fitted with electric ignition. Its performance at the Southampton motor boat contest and its large adoption for small boats speak for themselves as to its qualities. It is shown complete in Fig. 141.

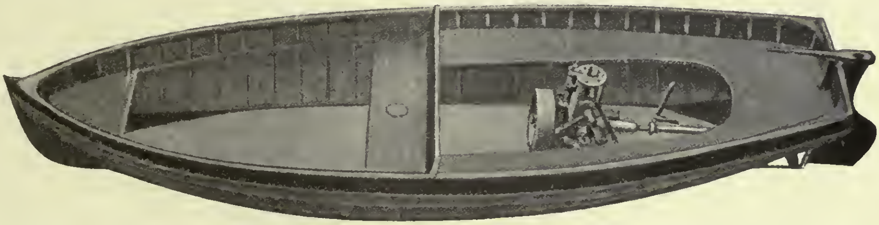


FIG. 143.—Small Motor Boat.

The tidy appearance of a small motor boat on the water is shown in Fig. 142. It is 18 feet long, 5 feet 9 inches beam, and is run with a $2\frac{3}{4}$ horse-power paraffin motor manufactured by the Seal Motor Company of Hammersmith. The boat is shown on its trial run. It is now busily at work lobster-fishing in Scottish waters, and is capable of running a good five knots for hours in succession.

The general arrangement of a small boat, the *Popular*, by Messrs. Lister & Sons is shown in Fig. 143. The engine is of the 2-cycle type, and may be made to use paraffin. This little craft has 18 feet of seating, and is sold at a reasonable figure, £64 complete running.

All the small craft under 20-feet L.W.L. are fitted with reversible propellers, the blades being movable. Fig. 144 shows the Motor Castings Company's outfit complete, with a 2-cylinder motor which has been introduced by this company, giving little vibration in comparison with the 1-cylinder with large bore and stroke. The bore of this engine is 65 millimetres, with an equal stroke. It is fitted with a silencer, pump, and carburetter, with throttle attached to the engine itself, and the whole engine work occupies a space of only 18 inches square by 18 inches high. The reversing lever and quadrant (which is fitted with a thrust block to take the reverse) is also fitted with the shaft on to the engine. The two blades for the propeller are fixed into the torpedo-shaped boss, and the stern tube is provided with the usual glands and the holding band for the outside of the keel. The whole apparatus measures from the fly-wheel of engine to the middle of the stern tube 52 inches. This length of shaft can of course be varied to suit the requirements. Messrs. Flower & Co.'s Nauticus feathering propeller is shown in Fig. 145, partly in section, showing three level wheels for moving the blades.

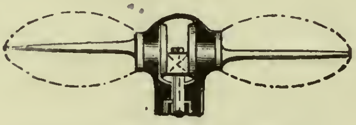


FIG. 145.—Feathering Propeller.

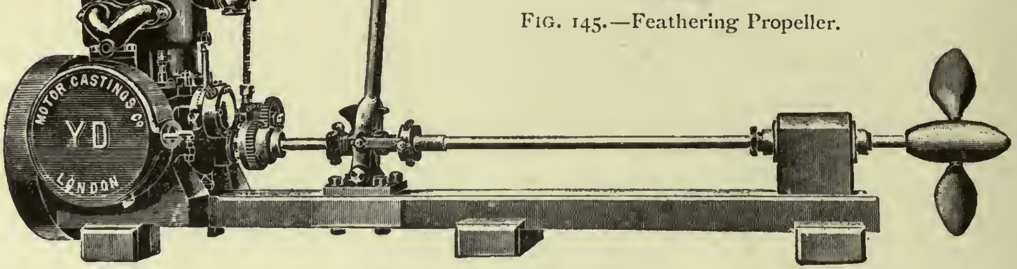


FIG. 144.—Motor Boat Outfit.

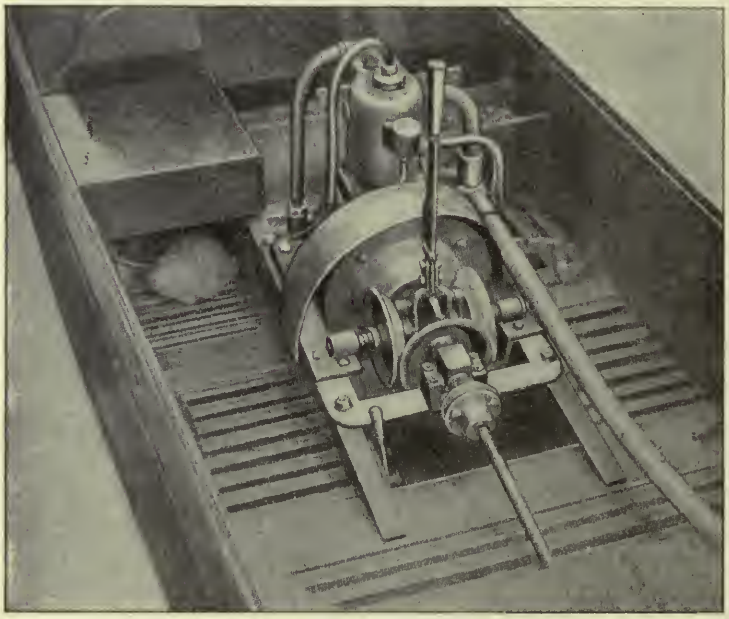


FIG. 146.—Motor with Bevel Wheel Reversing Gear.

In the larger craft, reversing gearing is better than reversing propellers. An arrangement of bevel wheel gearing, fitted in a boat shown in Fig. 146, gives a good idea of this type. Bevel gearing with a spring clutch is a very satisfactory form, and is better than some of the more recent types invented.

A SWEDISH MARINE MOTOR

This motor by the Vagnfabriks Södertelge has been fitted to several boats, and given great satisfaction in the matter of regulation of speed. The description and longitudinal section (Fig. 147) are from *The Yachtsman.*

A mixture of gas and air cannot be diluted indefinitely; if it be weakened beyond a certain point, explosion no longer takes place: thus all methods of regulation depending on variable proportions of gaseous working fluid and air are necessarily restricted within fixed narrow limits. At the same time such a method of regulation has many advantages over the present threefold combination of variable volume, variable composition, and varying time of ignition. Referring to the illustration, there is a throttle valve (not shown) immediately before the inlet valve H, G is the exhaust valve, and N an air valve placed in the tube-like port P and removed as far as possible from the admission valve. The air valve is closed by a spring, the tension of which is so adjusted that the valve does not open until the admission of the explosive mixture is throttled beyond a certain point. As the negative suction pressure due to the downward motion of the piston is constant, it follows that, if the inlet be strongly throttled, air will be sucked through the valve N to make up for this. Owing to the special arrangement of ports and formation of the combustion chamber, this aspired air does not mix with the explosive mixture, which at the point of firing is retained in G, while P is filled with air. It is further claimed that the stratum of air over the piston and in the port P tends to soften the shock of the explosion, and in this way decrease the noise of running inherent in explosion engines. This combination of an automatic air valve with a hand-controlled throttle is stated to form a self-acting governor. To quote the inventor's own words: "It is evident that, when the mixture is weakened by the admission of a larger quantity of air, the force of the explosion is also weakened, thus diminishing the power of the motor. Also, with a given position of throttle valve, if the load on the motor be increased (thus reducing its speed), a greater quantity of explosive mixture will be aspired during the suction stroke, on account of the lessened piston speed; the explosions are therefore stronger, and the motor gets up to its increased work. The motor automatically adjusts itself to a varying load." The time of ignition is invariable, and takes place a little before the dead-point. Only one regulating lever is used—the throttle-valve lever.

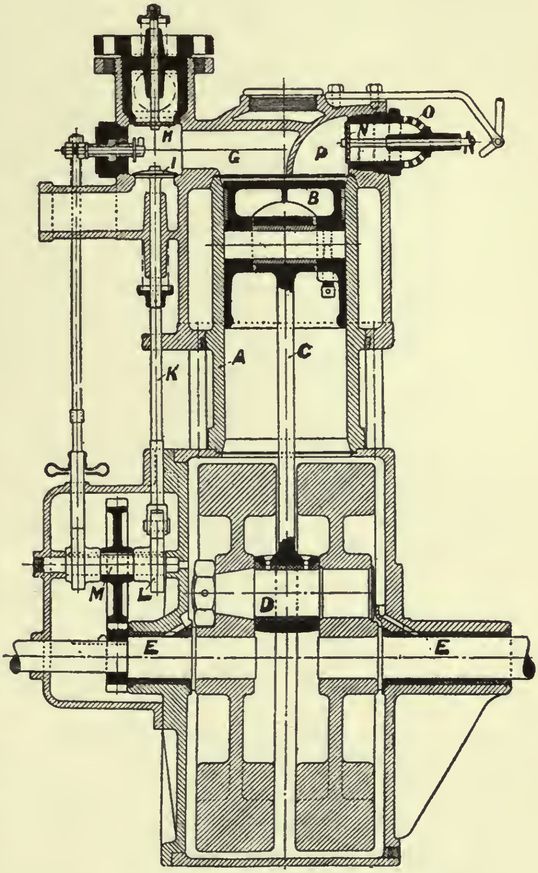
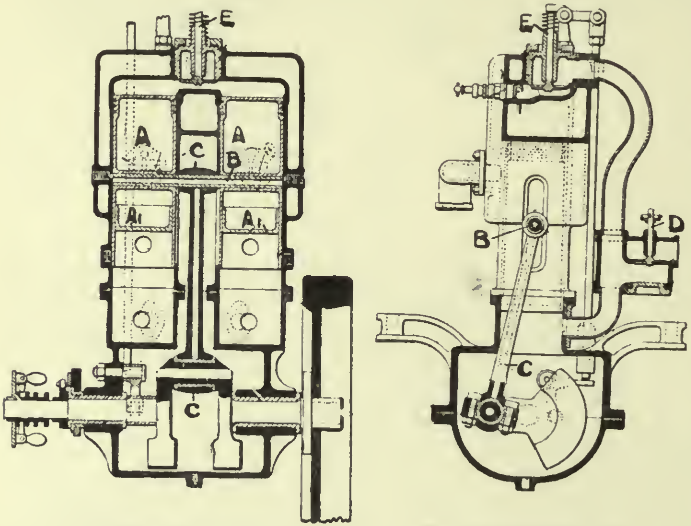


FIG. 147.—Regulating Motor, Longitudinal Section.

A TWO-STROKE ENGINE

The Giband 2-stroke double-cylinder engine—a new engine, described as follows, and of which Fig. 148 shows longitudinal and transverse sections respectively:—It has two working cylinders, that are cast in one piece and lie side by side. Exceptionally long trunk pistons A are used, which are rigidly connected together by a common pin B, that passes through a slot cut in the cylinder walls to receive it. A single connecting rod C is fixed to that portion of the pin which lies between and is outside both cylinders, so that it works in a chamber of its own, the lower part of which is in free communication with the crank chamber proper. In the upper part of the crank chamber are formed two cylinders, which are joined to, and constitute the lower parts of, the main cylinders. They are closed in at their lower ends, and therefore have no communication with the interior of the crank chamber proper. The pistons are fitted with partition plates A_1 near their lower extremities, and their under sides are used for compressing air in the lower portions of the cylinders. The length and arrangement of the pistons is such that when at the top of the working stroke they still entirely close the slots in which slides the connecting rod pin B. On the upward stroke the compressor pistons draw the carburetted mixture into the lower end of the cylinders through the atmospheric inlet valve D, situated behind the engine. The downward stroke compresses the mixture, which at the beginning of the upward stroke is admitted to the working cylinders through the mechanically operated inlet valve E in the top of the cylinder head. There it is ignited after having been again compressed, in the usual way, simultaneously in the two cylinders. During the latter part of the down stroke the piston uncovers the slot communicating to the connecting rod chamber, and through this the burnt gases are forced to escape, partly by their own initial pressure, and finally by the incoming mixture.



Longitudinal Section. Transverse Section.

FIG. 148.—Two-Stroke Engine.

Lubrication is effected from the crank chamber through the hollow crank pin, up the hollow connecting rod, into the hollow gudgeon pin, and so out into the cylinders. As will be seen from our illustrations, only one ignition plug is employed for this engine, which thus works as a single-cylinder motor on a 2-stroke cycle.

By this design many of the disadvantages of using the crank chamber as a part of the air pump are overcome, the chief objections to which are its ineffectiveness as a pump, owing to the large waste capacity of the crank chamber, and the difficulty of lubricating the moving parts properly without allowing the oil to be taken into the cylinder with the explosive mixture.

PUMPS AND ENGINE FOR JET PROPELLERS

The double pump, combined with an 8-cylinder engine of the author's design, is shown in the Fig. 149 in side elevation with one of the pumps in part section. The conoidal disc of the pumps is shown at VV, the whirlpool chamber at W, and the volute or snail shell S, with a common intake at A.

The end view (Fig. 150) shows the two discharge outlets for port and starboard propellers.

There are certain advantages in multiple-cylinder engines, the chief of which is the cooling of the piston and cylinder more readily in a small than a large cylinder, and also the more even and regular turning of the crank shaft. The strains and stresses are distributed over larger bearings and areas, and at no point very intense; besides, the centre of gravity is lower and the total height less. All these are of considerable importance on a vessel. This plant is designed for an 800 horse-power vessel with gas producers working on the suction principle, and is shown in the vessel in Fig. 128, p. 110. As an example of a multiple-cylinder motor, the 12-cylinder motor of Craig-Dörwald design is interesting. It is shown in Fig. 151 with diagonal cylinders.

Compactness has been the chief object aimed at in designing the 12-cylinder petrol engine manufactured by the Putney Motor Company, for, by reducing the over-all dimensions as far as possible, the engine not only takes up less room, but the total weight can be reduced, and the

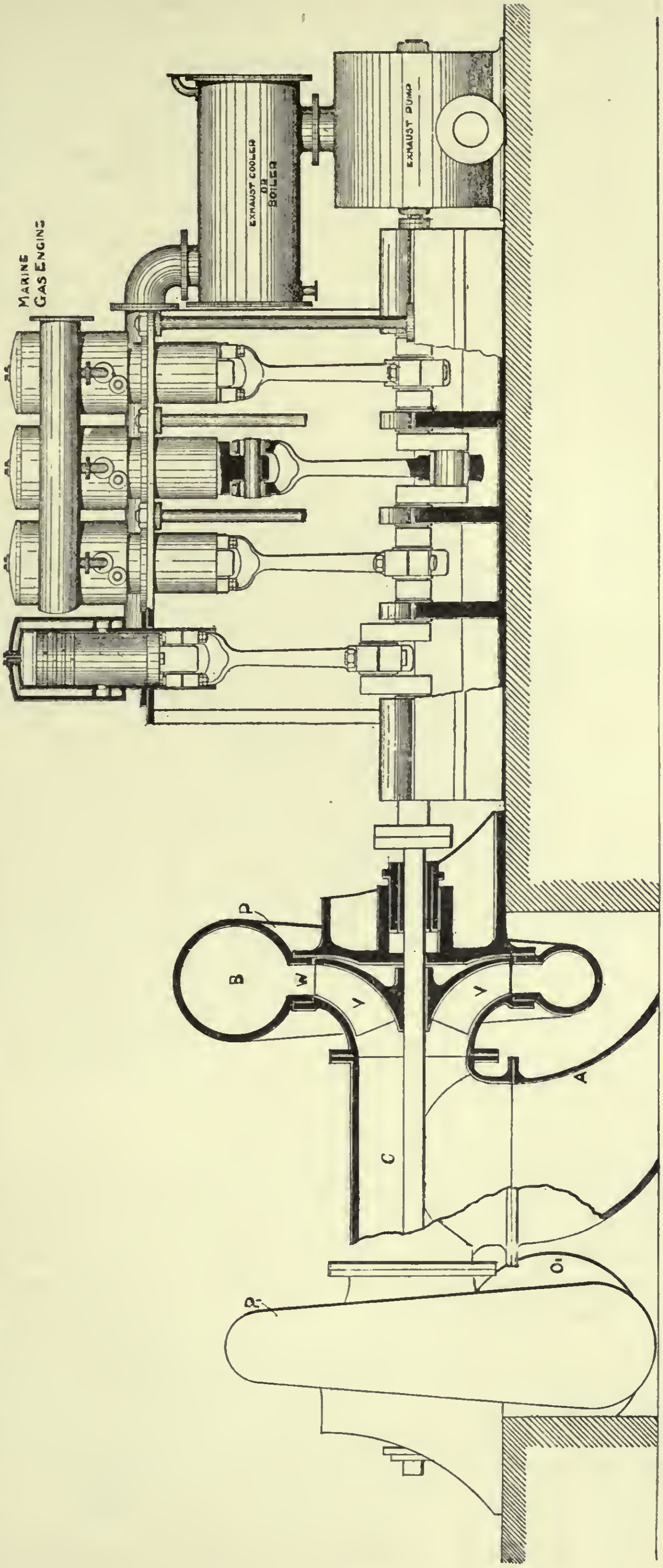


FIG. 149.—Engine and Pumps for Jet Propellers. Sectional Elevation.

pipe connections between cylinder and cylinder be simplified. From Fig. 151 a very good idea of the complete engine can be gathered, and it will there be seen that the cylinders are placed diagonally—six on each side of the crank chamber—and that all the valves are on the inner side of them. There are two peculiar features, in particular, about this engine, for, in the first place, the cylinders are not radial to the crank shaft, and, in the second place, it has its cylinders grouped in three sets of four, so that each set acts upon a common crank pin. Another noticeable point is that all twelve valves are operated by one cam shaft, and that there are duplicate cams for each valve, to enable the direction of rotation of the engine to be changed by sliding the cam shaft longitudinally in its bearings. Primarily intended for launch work, the engine runs at a normal speed of 1000 revolutions per minute, it develops from 130 to 150 brake horse-power, and its total weight, including the fly-wheel, is about 980 lbs. Its over-all dimensions are 4 feet 3 inches (length) by 2 feet 8 inches (width) by 2 feet (height). Each cylinder has a bore of $4\frac{7}{8}$ inches and a stroke of 5 inches.

The cylinders are cast in pairs, and each of these castings is identical with those employed for the ordinary type of 2-cylinder and 4-cylinder vertical engines. The inlet and exhaust valves lie alongside one another in the same valve chamber, and there are separate inlet and exhaust ports leading to each valve from a face joint on the outside. The cylinder heads are jacketed in the usual way. All the valves, which are interchangeable, have cast-iron heads, with steel spindles that are screwed in while the heads are hot. Inspection covers screw into the cylinder casting above each valve — those above the inlets receiving the ignition plugs—and there are half-compression cocks above each cylinder.

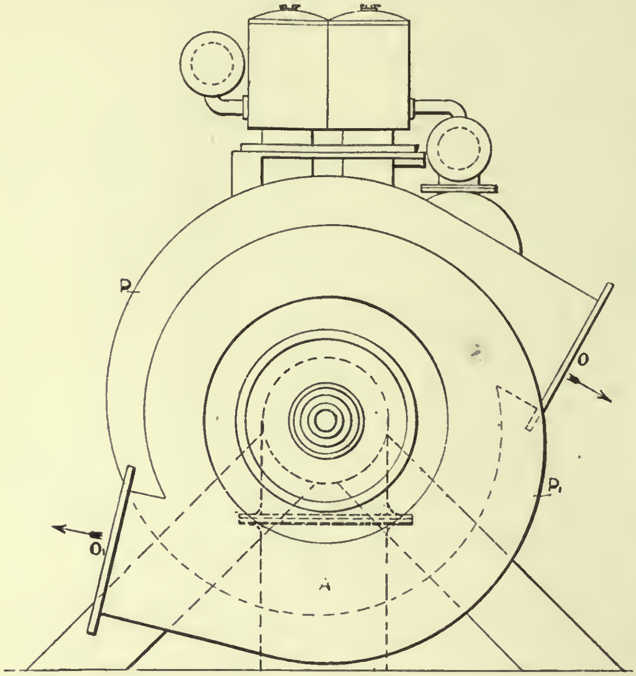


FIG. 150.—Engine and Pumps for Jet Propellers. End View.

The crank chamber, to the upper part of which all the cylinders are bolted, is made in two pieces. The joint between the two castings passes through the main bearings, but, instead of being quite horizontal, is at right angles to the resultant thrust line of all the cylinders. The faces to which the cylinders are bolted are at 45° from the vertical, but the cylinders on the one side are on a lower level than those on the other side, because the axes of those on both sides are given a slight "advance" in relationship to the crank shaft. The centre line of any cylinder is $\frac{5}{6}$ths of an inch from a radial line drawn parallel to it from the centre of the shaft, and this gives an "advance" of $\frac{1}{6}$th of a stroke for forward running.

The crank shaft, which is made of nickel steel, is a particularly fine piece of work. Each portion of the shaft, as also the crank pins, are hollow, while the crank cheeks are slotted out, to still further reduce the weight. The shaft has three crank pins, upon each of which two opposite pairs of cylinders operate. This multiple-cylinder engine design may also be observed on the Napier 6-cylinder engine on the most powerful racing launch, shown in Fig. 152.

The engine, which is to be a very powerful 6-cylinder Napier model of an entirely new marine type, will be placed slightly forward of amidships, with its crank shaft parallel to the water-line. Its weight has been cut down to a considerable extent, but not so much as to in any way affect durability. The cylinders, which are cast separately with their water jackets, have a bore of 8 inches, the stroke is 6 inches, and the normal speed is 1000 revolutions per minute, at which speed it is rated at 150 motor-power, although the engine may be expected to develop about 200 horse-power. The valves are on opposite sides—inlet valves on the port side, and exhaust valves on the starboard side. The exhaust gases from each cylinder are separately led to a water-cooled silencer H, placed alongside the engine, and from the silencer the outlet pipe will pass astern to the exhaust funnel. The engine fly-wheel E, which is placed forward, is particularly small, on account of being gear-driven at high speed from the crank shaft by the two spur wheels E_1 and E_2.

The clutch A, which is put aft of the engine, is also very small; it is of the cone type, runs in an oil bath, and has been specially designed to meet the particular requirements of marine propulsion, namely, a clutch which can be eased in and out gently to allow a large amount of slip if occasion requires, can quickly be locked in tight to give a very positive drive, and can yet be equally easily withdrawn. The clutch A is operated by the hand lever A_1, which is put to the right of the steering wheel D, while, in conjunction with it, is arranged a brake on the tail shaft that is automatically applied when the clutch is fully disengaged.

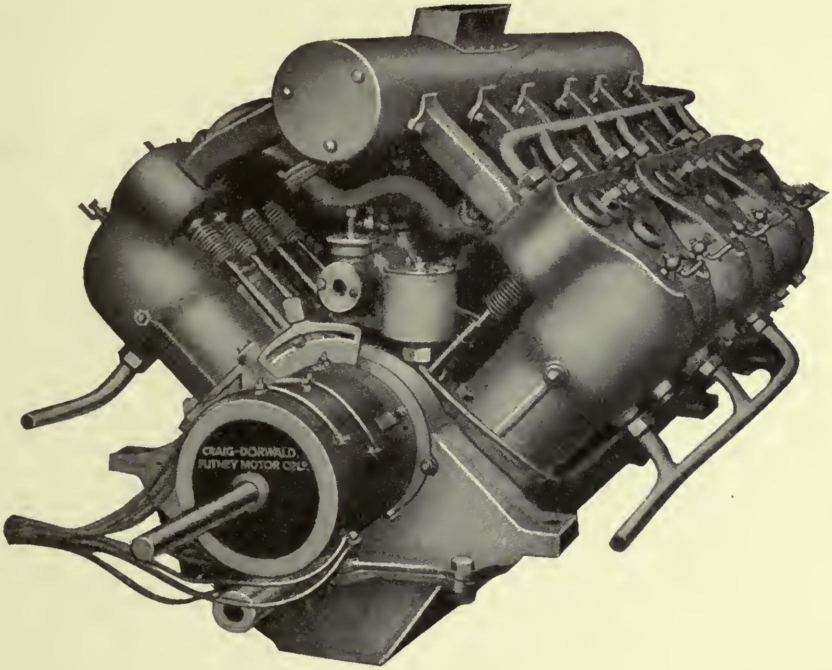


Fig. 151.—Twelve-Cylinder Engine.

Behind this clutch is the universal joint B, which is necessary on account of the obliquity of the propeller shaft to the engine. The Napier Company have been developing their special universal coupling for about two years, and claim to have now produced so perfect a device that they have no hesitation in fitting it in a powerful boat like this. Its use permits of the engine being placed in a lower position, and parallel to the water line, so that the lubricating oil does not flood the after cylinder. The reversing gear, which is of the standard Napier pattern, is enclosed in the box G, situated aft of the universal joint. It is operated by the hand lever C_1, which can also be controlled by

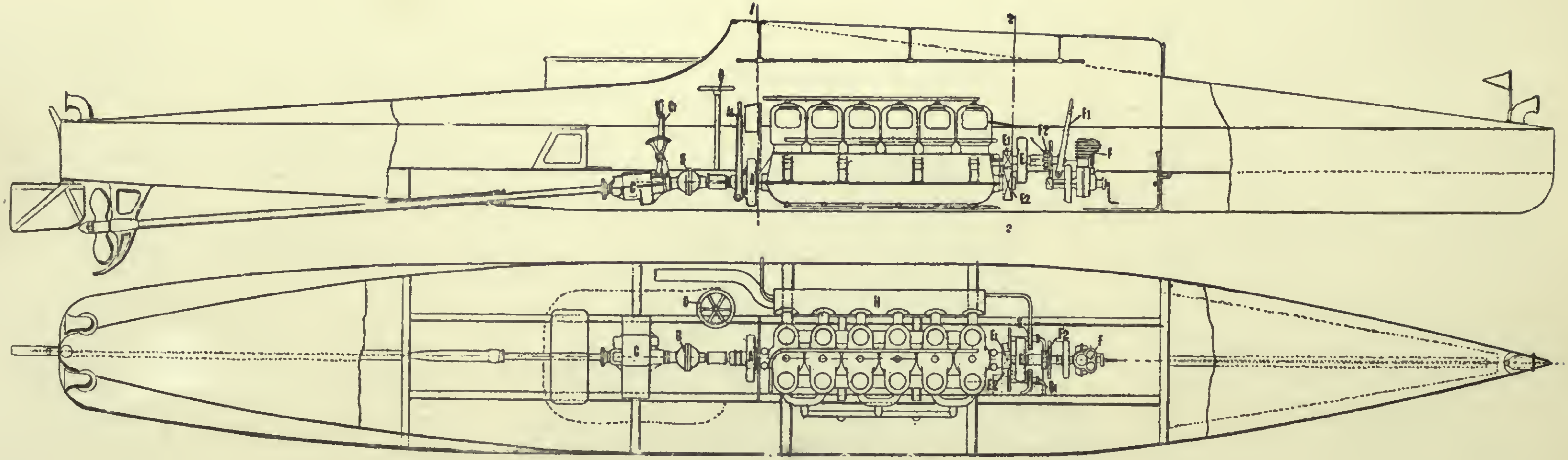

1
2
F1
F2
F
E1
E2
E
G
C
B
A
H

FIG. 152.—Napier Racing Motor Launch.

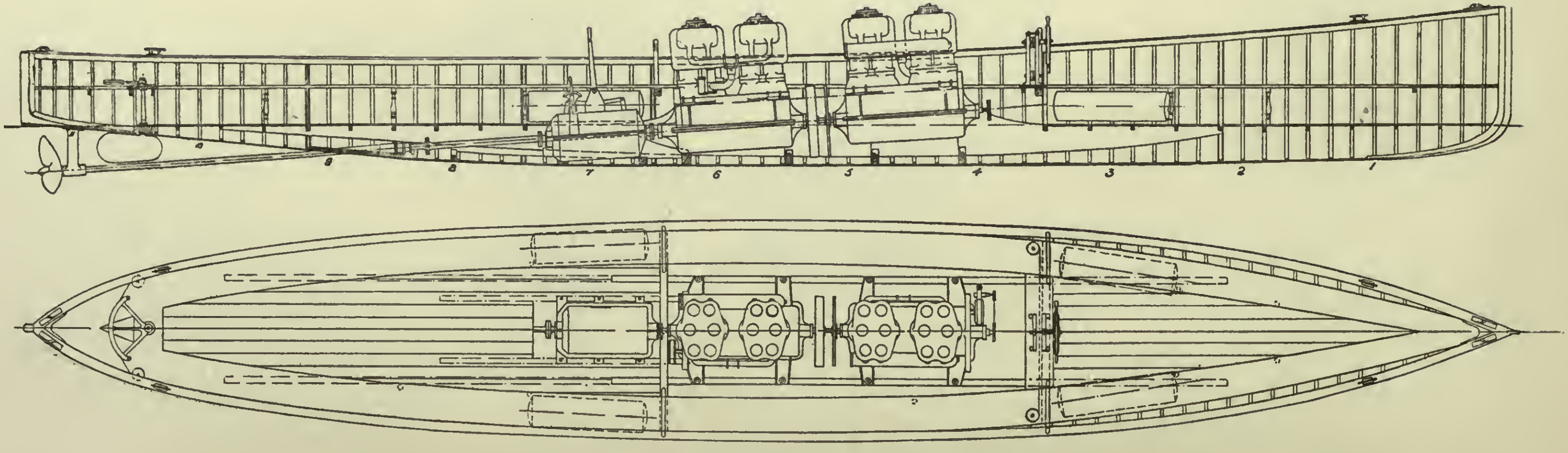


FIG. 153.—Thornycroft Racing Motor Launch.

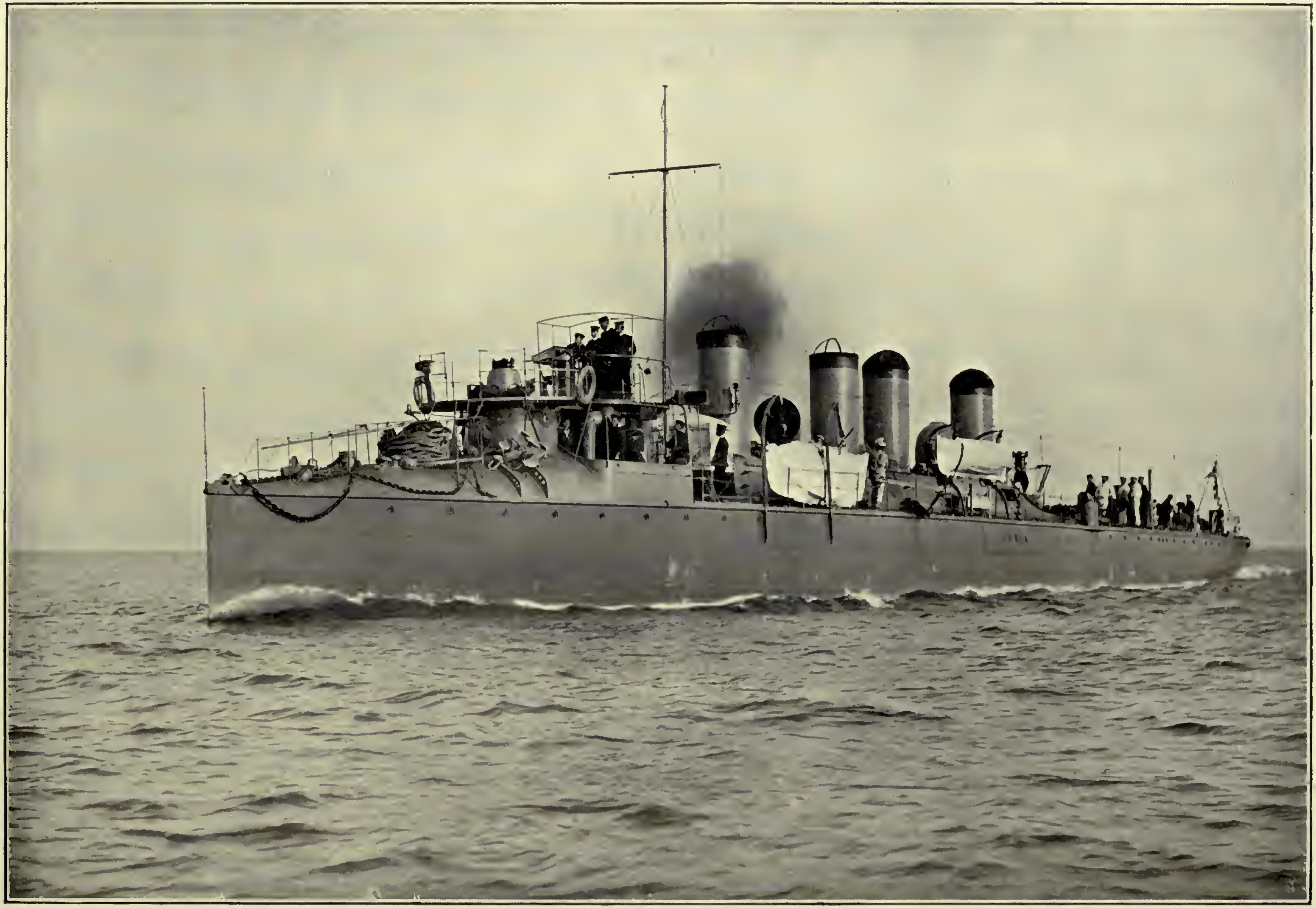


PLATE V.—31-KNOT TORPEDO BOAT DESTROYER OF THE IMPERIAL JAPANESE NAVY.

the driver, and gives a direct-through drive when running "ahead." Messrs. Yarrow & Co. are to design the propeller, and are carrying out some extensive experiments for this purpose: at present we are unable to give any particulars as to the size and pitch. The thrust bearing is arranged inside the reverse gear box G.

Forward of the main engine is a small single-cylinder motor F for starting. The crank shaft of this small engine is geared to the fly-wheel shaft of the main engine, a friction clutch and free-wheel coupling F_1 being interposed to allow the larger engine to overrun the smaller when once started. The starting lever F_2 is used to throw the small starting motor into gear with the main engine; the starting motor is about 4 horse-power, and is capable of rotating the large engine, which is then started off the switch. This small motor is also connected to a bilge pump for use in emergency. Two circulating pumps G and G_1 are fitted, that on the starboard side being used to pass the water through the silencer, and also to empty the bilge.

This multiple-engine arrangement is also shown in Thornycroft's cup racer boat, with two sets of engines of four cylinders each (see Fig. 153), and for the general arrangement of these boats the two examples here given show the present practice in England.

MOTOR BOAT ACCESSORIES.

The ignition plugs require some attention.

Many motor boat users must have already experienced considerable trouble from a sparking plug, which has either become coated with moisture from dew or sea air, or from water thrown over it accidentally. Presuming that a sparking plug is fitted in an unprotected spot, there is no more likely cause for misfiring than dampness on the body of the plug. A new plug (Fig. 154) with an insulating cap has just been placed on the market by the General Electric Co., of 71 Queen Victoria Street, London. The insulating cap is made of a mechanically strong and heat-resisting material, which is a perfect electrical insulator. This cap is attached to the plug by means of a coarse thread, as the illustration shows, and fitted to the head of the cap is a small spring buffer, which serves as a terminal for the high-tension wire, and forms a connection with the centre conductor of the plug. The high-tension wire can be screwed into position in the plug, and the whole can then be made absolutely water-tight and damp-proof by sealing up the open head with insulating compound. To renew the sparking plug the cap can be unscrewed, bringing away the high-tension wire and spring buffer. A new plug can then be inserted. A further advantage of the cap is that the porcelain centre insulation of the plug is not subjected to rapid or great changes in temperature, and so the risk of the porcelain cracking is to a great extent avoided.

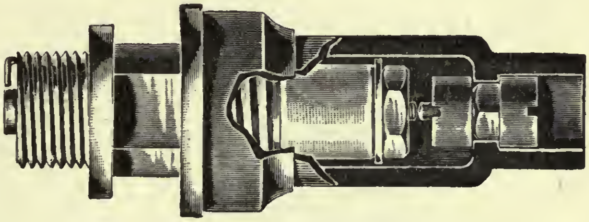


FIG. 154.—Sparking Plug.

The ignition itself is of great importance, and, having some considerable experience of the difficulties of marine engine ignition, the author found it necessary to devise an ignition apparatus for the purpose for his own boats.

The battery, coil, and sparking-plug system works very well indeed, but the continual charging of the battery is a drawback, especially in boats which may be caught with a discharged battery far away from a recharging place.

The high-tension magnetos in the market were considered far too complicated, heavy, and expensive, and few engineers could be trusted to repair them if deranged.

A system was therefore designed to work with a simple low-tension magneto, to take the place of the battery in the ordinary high-tension system in common use, so that it can work either with the battery or magneto as desired.

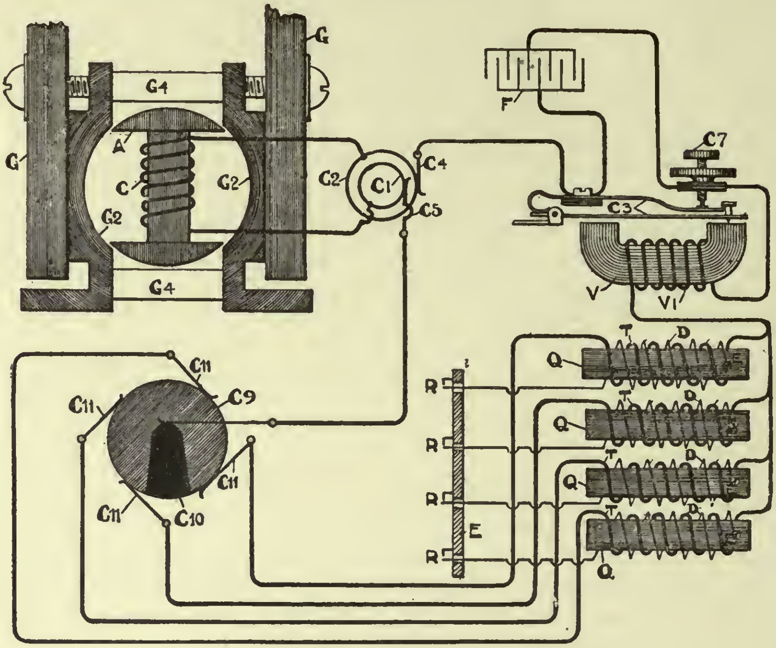
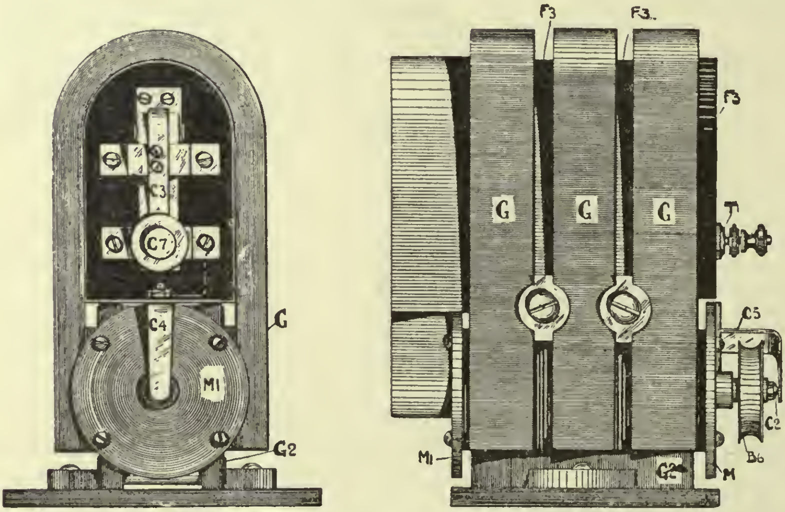


FIG. 155.—Kennedy's Magneto-Ignition System.

The system was fully described in the *Automotor Journal* of 5th November 1904, from which an abstract is taken.

Fig. 155 shows a diagram of the electrical connections for a 4-cylinder engine.



End View. Elevation.

FIG. 156.—Kennedy's Ignition Magneto.

In the upper left-hand corner the method of attaching the pole pieces G_2 (by means of set screws) and the arrangement of the solid brass distance pieces G_4 are shown. To the right is a drawing of the trembler C_3 and C_7, which, besides being diagrammatic, also shows the design of this part of the apparatus.

For diagrammatic purposes the ends of the armature winding are shown in Fig. 155, as if they were connected in two slip-rings C_1 and C_2, but, as will be seen in Fig. 156, they are in practice led to contact knobs on the ends of the armature spindle. A wire is led from C_1, which constitutes the live end of the armature winding, to the *low*-tension distributor C_9. This *low*-tension distributor takes the place of the *high*-tension distributor employed in other high-tension magneto-ignition systems, and in Fig. 157 it is diagrammatically represented in the same way; but it must be understood that the distributor C_9 is only used in connection with the *low*-tension circuit. The distributor C_9 is set on the cam shaft of the engine, or on some other half-speed spindle, and is arranged so that it can be rocked relatively to that shaft for timing purposes. The distributor segment C_{10} feeds the low-tension current to each of the low-tension distributor brushes C_{11} in turn. Each of these brushes C_{11} is connected to the primary winding T of a separate induction coil, so that for a 4-cylinder engine there are thus four distinct induction coils. The other ends of these primary windings T have a common connection with a wire, which is connected to the coil of wire V_1, which is wound on the iron core V, the coil and core being used solely for operating the high-speed trembler blade C_3.

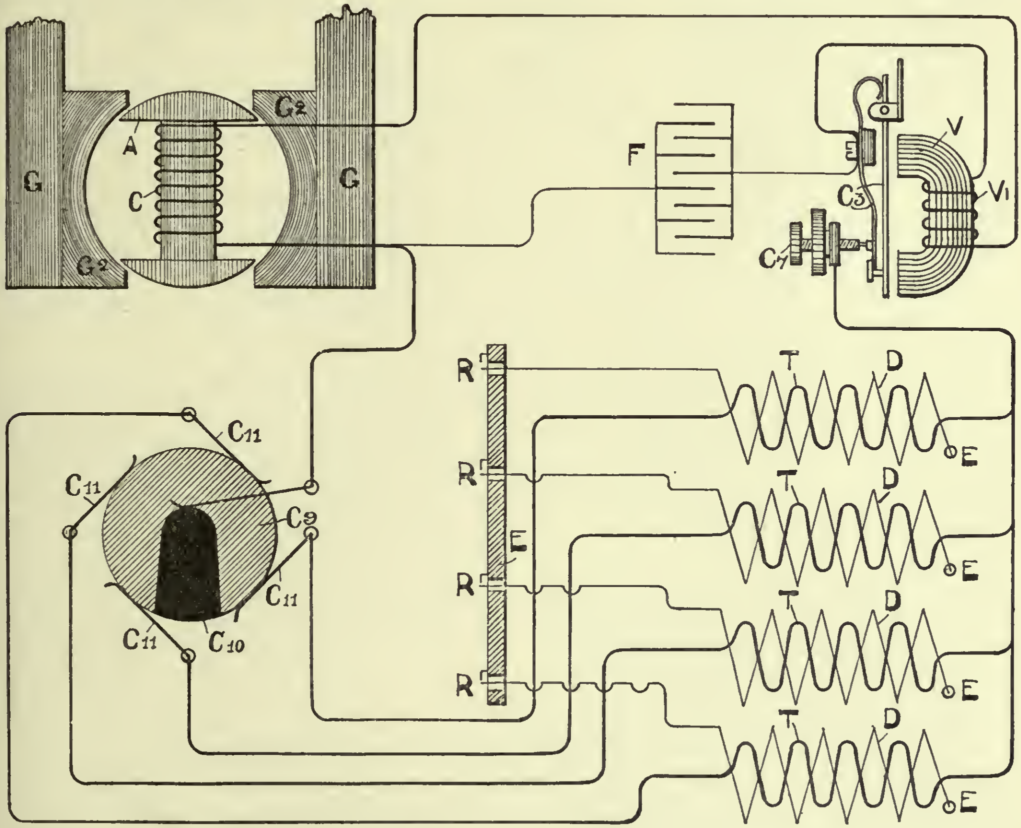


Fig. 157.—Kennedy's Magneto-Ignition System with Tesla Coils.

A condenser F is "shunted" across the trembler contacts C_3 and C_7—which are connected respectively to the collector brush C_4 and the coil V_1—and acts in precisely the same manner as described in our introduction. It will be noticed, however, that the only circuit through which the condenser can discharge includes the armature coil C and the supplementary coil V_1. The secondary coils D are each permanently connected to their respective ignition plugs, further distributing gear being no longer necessary, since the distribution is effected in the primary circuit.

It will be noticed that the armature coil C is not normally run on closed circuit, as is the case in other high-tension magnetos. An advantage of this system is that it does not require a positive drive, and does not therefore require any setting. By distributing the low-tension current, a high-tension distributor is rendered unnecessary.

TABLE OF REFERENCE LETTERS FOR RANKIN KENNEDY HIGH-TENSION MAGNETO IGNITION.

A	Armature core.	F	Earth.
B_6	Pulley wheel.	F	Condenser.
C	Armature coil.	F_3	Condenser case.
C_1	Armature coil, live end.	G	Magnets.
C_2	Armature coil, earthed end.	G_3	Magnet pole piece.
C_3	Trembler blade.	M	Bearing plate.
C_4	Contact spring (live).	M_1	Bearing plate.
C_5	Contact spring (earthed).	Q	Induction coil cores.
C_7	Adjustment screw.	R	Ignition plugs.
C_9	Low-tension distributor.	T	Primaries of induction coils.
C_{10}	Distributor segment.	T_1	Primary coils, live ends.
C_{11}	Distributor brushes.	V	Core for trembler.
D	Secondary windings.	V_1	Coil for trembler V.

The magneto is only 5 lbs. weight and 6 inches in height over all.

Since the above description was written, a further improvement has been introduced in the shape of coils having no fine wire winding and no iron core, the condenser being in series with the break. This arrangement is shown in diagram, Fig. 157.

The low-tension arcing system was also tried with various circuit-breaking devices in the cylinder, both electrical and mechanical, but all of them failed to work satisfactorily.

The great advantage of the small magneto generator is that it can replace any battery or accumulator working with a trembler coil, without any alterations in the system except a slight adjustment of the trembler.

PUMPS FOR CYLINDER COOLING WATER

These are of four kinds—rotary, centrifugal, plunger, and semi-rotary. The plunger and semi-rotary are positive pumps, so also to some extent is the geared rotary.

The simplest rotary pump is shown in Fig. 158, and consists of a simple casing with two gear wheels of large pitch, working somewhat on the principle of Root's blowers. It is shown with the front cover removed, and is a slow-speed pump.

The centrifugal pump is shown in Fig. 159. The water enters at the centre, and is given a whirling motion by the curved vanes, thus producing a pressure which drives the water through the cooling system.

The semi-rotary pump, shown in Fig. 160, is made by several people; it works fairly well, but the valves are apt to clog up in dirty waters.

The plunger pumps are well known in their many forms. It is the pump used by some leading makers. In Fig. 161 a view of the excellent 2-stroke motors made by Messrs. King & Co., Limehouse, London: this form of pump is shown driven off an eccentric on the shaft end. It has the merit of being absolutely a positive pump.

MOTOR BOAT PROPELLERS

In regard to small propellers an eminent boat designer may be quoted here, as he fairly sums up the position :—

With regard to design as applied to propellers, one cannot speak with certainty. Than this there is no subject in all the range of naval architecture and marine engineering so lacking in reliable data. After all the years of practice, the most efficient screw for a specific purpose remains very much a question of experience or chance. The rather costly procedure of trying various screws on the finished ships is still in vogue. And the importance of the subject warrants even the adoption of this method. Slight alterations in blade area, pitch or diameter, often effect most wonderful economies, and the subject has for many years been receiving the attention of engineers and shipbuilders alike.

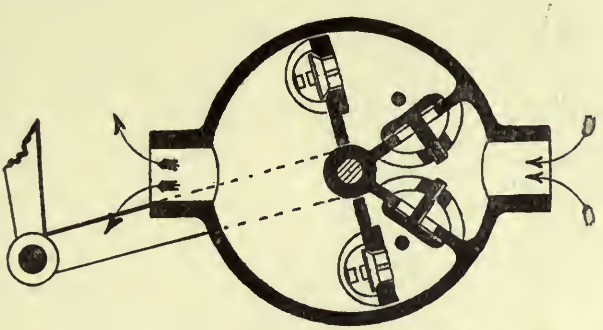


FIG. 160.—Semi-Rotary Pump.

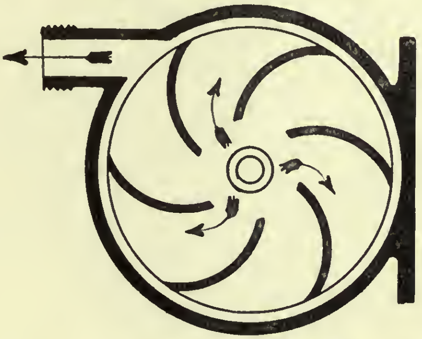


FIG. 159.—Centrifugal Pump.

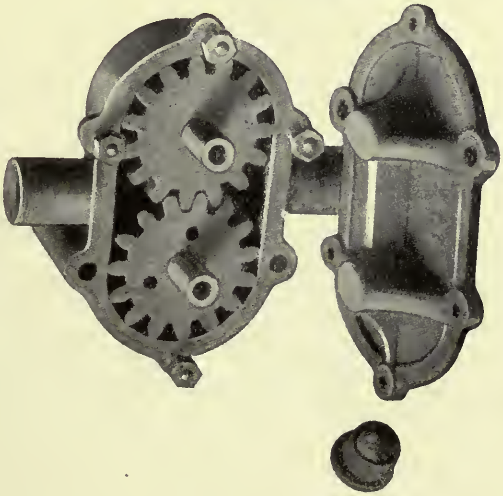


FIG. 158.—Rotary Pump.

Types of Circulating Pumps.

In the choosing of the most effective propeller the motor boat has a great advantage over larger work, inasmuch as the necessary experiments may be carried out at trifling cost. And it would be well if both motor and launch builders gave this their careful consideration, tabulating systematically the results of experiments and the conditions under which these were carried out. The results obtained in steamship practice indicate that such experiments would prove highly remunerative to the experimenter and instructive to the world at large.

One of the greatest questions with regard to propellers in speed launches with fast-running engines is the stopping power, and the great want of this power in the modern product constitutes a grave danger. Take a motor car without its brakes and you have a somewhat similar case. A marine brake is necessary ; but it is difficult to see it in a propeller which is revolving at anything between 1000 and 1500 revolutions per minute. Owing to the construction of the screw, it is not possible to get a reversible propeller which will be an efficient one ;

and, in spite of the various reversing clutches and gears, this question of reversing remains one of the weakest points in the marine motor; this, however, is a question for the engineer rather than the naval architect.

My own efforts in this direction have been mostly in the direction of the jet propeller, but it, as a propeller, is best suited for large powers and not recommended for vessels under 25 or 30 feet in length, although in our experiments it did as well, if not better, in a 20-feet boat than the best propeller screw with the same engine.

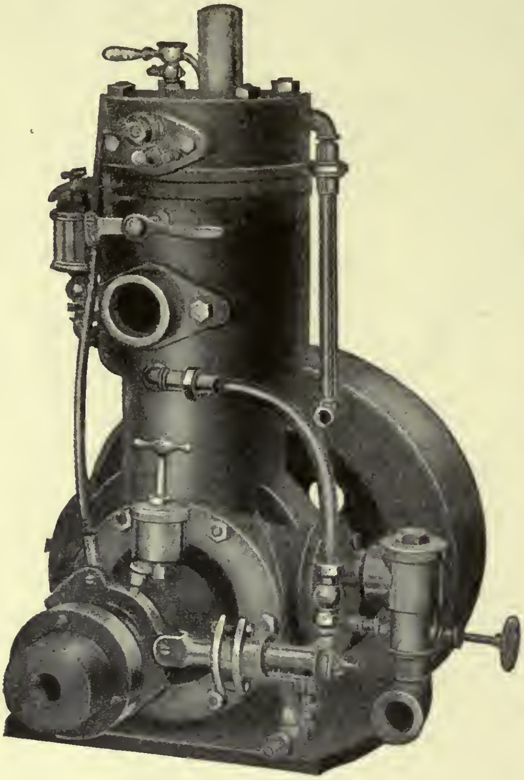


FIG. 161.—Engine with Plunger Pump.

THE EXHAUST OF MOTOR BOATS

In the combined engine and gas turbine, the exhaust is effectively disposed of in producing additional power. This procedure, however, is not always applicable, especially in small boats. A silencer is necessary to quiet the exhaust, and, as red-hot exhaust pipes in a small boat are not pleasant, some means of cooling the exhaust is desirable.

As an example of a practical system of exhaust cooling and silencing, the Lozier system is shown in Fig. 162.

In the Lozier system the water is taken from below the hull at any convenient spot, and then passes through the inlet pipe A, past the screw-down valve B, through the non-return valve C to the centrifugal pump (not shown in drawing) which circulates the water around the cylinder D. The exhaust pipe is led out from the cylinder horizontally for about 2 feet, and then by means of a couple of bends is taken into the first exhaust box F; from the first box the waste gas goes into pipe G, into the second exhaust box H, and then out by pipe I to below the hull J. The water outlet from the cylinder D is in the form of a jacket to the exhaust pipe E, which it completely surrounds, as shown at K. At the joint L the water is led from the jacketed pipe up through pipe M, past the joint N, through the screw-down valve O into the exhaust box F. Inside the first exhaust box the water leaves the continuation of the pipe M in the form of a very fine spray, and then runs away down the pipe G into the box H and through pipe I, finally emerging at the brass cap at J. It will be seen that the cooling of the exhaust commences immediately it leaves the cylinder, but that a portion of the exhaust pipe is left unjacketed before it reaches the first exhaust box. The reason for not jacketing the entire length of pipe will now be explained. At the union N is a pipe P, with a screw-down valve at Q, the outlet being taken overboard at R. If the valve O is screwed down, no water can pass into the exhaust box, and it then finds its way over the side by way of the pipe P. If the valve Q is screwed down and the valve O is opened, the water circulates through the two exhaust boxes, or, if desired, a portion of the water can be sent in both directions. In winter it might be found desirable to send all the water overboard after leaving the jacketed exhaust pipe, whilst on a hot summer's day the converse would hold good. In arranging the different connections in a boat the important points to observe are: (1) to place the first exhaust box as high as circumstances will allow; (2) to have the two exhaust boxes tilted at the angle shown, so that the water drains quite clear; and (3) that the combined outlet pipe for the exhaust and water is at least 6 inches below the load water-line. Messrs. The Launch Motor Co. Limited, of Strand-on-the-Green, Chiswick, are introducing this system to the British market.

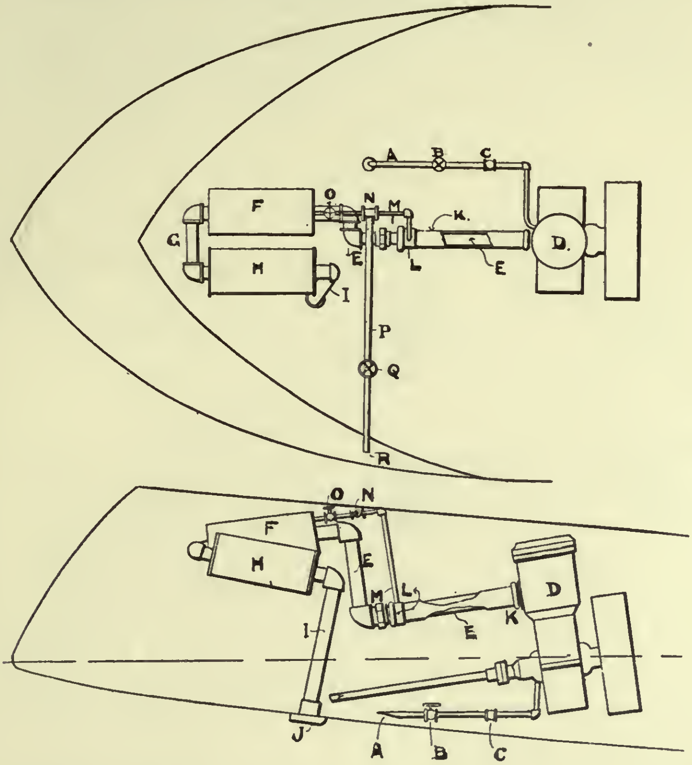


FIG. 162.—Plan and Elevation showing General Arrangement of Lozier Exhaust System.

Water-cooled silencers are now common on all motor boats.

An example of the Universal silencer is shown in Fig. 163. The entering gases expand in the first sphere, from which they emerge into a water spray, enter the second sphere much cooled and diminished in pressure, and again enter a water spray space to finally fall to a little above atmospheric pressure in the third sphere, from which they quietly discharge.

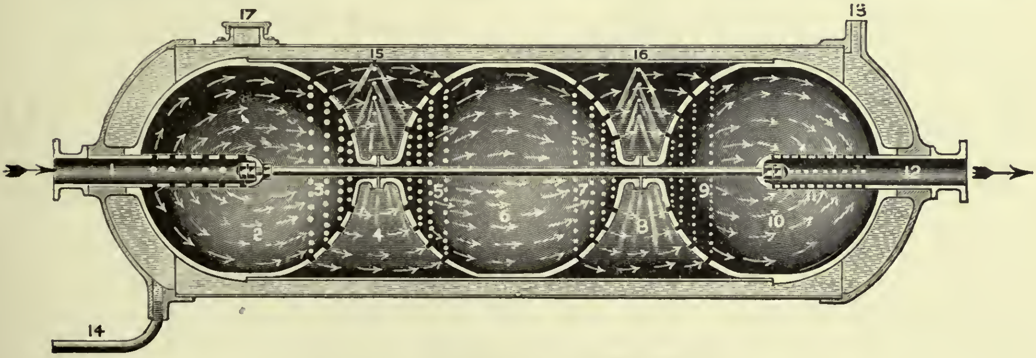


FIG. 163.—"Universal" Exhaust Silencer.

THE EXHAUST EJECTOR

This silencer and cooler was evolved during the author's experiments with jet-propelled boats and oil engines. It acts upon the injector principle: the exhaust gases, rushing through a discharge nozzle, induce a suction on an annular chamber connected to the water jackets of the engine cylinders, and draws water through them. All the circulating water may be passed in this way through the exhaust ejector by the suction of the gases; but a pump should be provided also, for it is not always advisable to pass all the cooling water into the exhaust ejector.

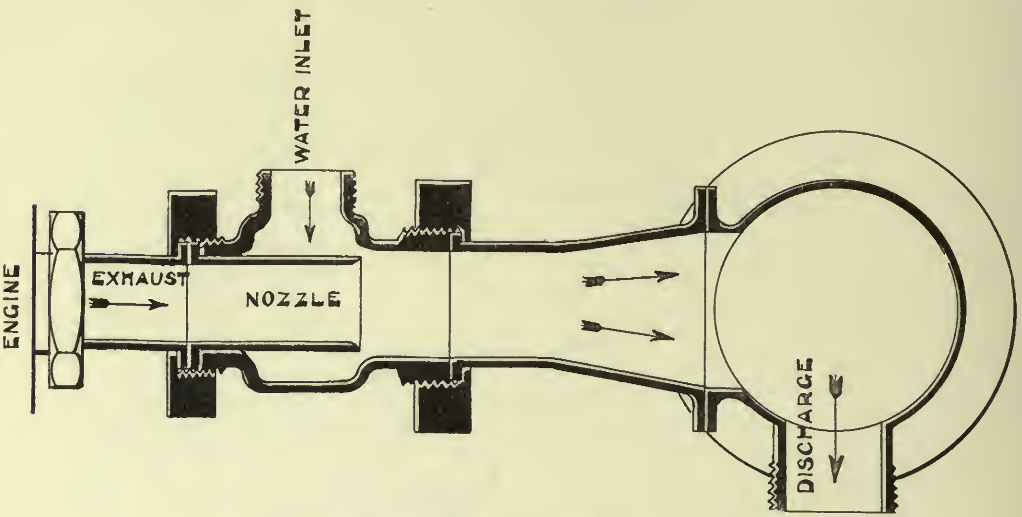


FIG. 164.—Kennedy's Ejector Exhaust Silencer and Cooler.

Referring to the Fig. 164, the exhaust passes through a short nozzle into the throat of an expand chamber. The water is sprayed from the annular passage, and, mixing with the gases, thoroughly cools and condenses them. They then, water and gas, escape from a common exhaust pipe, and are delivered below the water line.

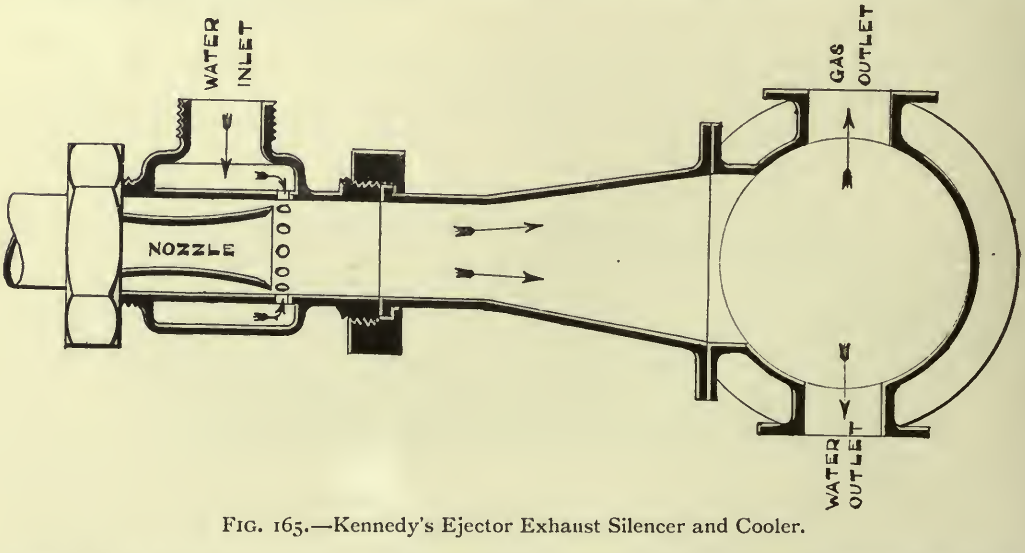


FIG. 165.—Kennedy's Ejector Exhaust Silencer and Cooler.

Fig. 165 shows a modification in which the water enters by a series of perforations, across which the exhaust blast blows and thereby induces a flow of water from the water jackets. The gases may be allowed to escape through a chimney apart from the water, which is allowed to run off below the water line.

As already pointed out in treating of large marine gas engines, the exhaust should be utilised, if not in a gas turbine, in a steam boiler. The heat of the exhaust will evaporate 2 lbs. of water per horse-power at 150 lbs. pressure. This steam can be usefully applied for some auxiliary purposes, especially where the engine is driven from a gas producer.

EXPERIMENTAL MOTOR BOAT JET PROPELLED

In Fig. 166, a side elevation partly in section, a plan, and a cross section, is shown the arrangement of the 20-feet boat employed in the test experiments made by the author on jet propellers. The boat was not built for the purpose, but was a fairly good vessel for the purpose.

The engine and its accessories are all shown, also the pump and one propeller only—that for going ahead. Very small pumps, about 2 or 3 horse-power, are not made highly efficient, and are generally very heavy; so that, to get any fair results, special pumps have to be made for propeller purposes.

The experiments proved that for boats under 30 feet length and slow speed the jet propeller is not as good as the screw, but for boats over 30 feet and for higher speeds the jet propeller has the advantages with internal combustion engines, and that, for auxiliary power on sailing vessels with oil petrol or producer gas engines, it would prove far superior to any screw. Moreover, it can so readily be fitted into any existing ship, although not built for power, that no yacht or trading ship need be without auxiliary power.

Referring to the drawings, the plant, it will be seen, occupies the middle of the boat, while the petrol or oil tanks are carried on the forward grating.

The engine is a petrol motor with one cylinder, 3⅜-inch bore, 3¾-inch stroke, speed about 800. The drive on to the pump was at first by belt, so that we could alter the speeds for experiments.

The drive is now by chain and sprocket wheels, as shown. The pump is a 4-inch suction and delivery, and gave a static pressure of 6 lbs. per square inch with the engine at full speed and an orifice area of jet of six square inches.

The total weight of the boat with everything aboard was 15 cwt.; with four men aboard, the weight totalled about 1 ton. A speed of 9 feet per second or 5.42 knots was observed. 6 lbs. pressure corresponds to 14 feet head, so that the velocity of the jet would be $8\sqrt{14} = 29.9$ feet per second, say 30 feet roughly. The area of jet, 6 square inches or .042 square feet, multiplied by the velocity, will give the cubic feet of water delivered per second $= 30 \times .042 = 1.26$, and 1.26×62.3 will give the weight of water discharged $= 78$ lbs. per second. The boat was too heavy, and its draught, about 16 inches when all aboard, was too much for the size of engine and propeller to get much speed, but it served the purpose of the trials.

The economy was increased by increasing the area of the jet until the jet velocity was twice the velocity of the boat, the boat's speed remaining about the same value as before. In the first case the water horse-power was equal to 2, and in the second case equal to 1.7.

High-speed vessels would suit best for jet propulsion, because the jet becomes comparatively smaller in proportion, that is, more horse-power per square inch of jet area can be put into it with efficiency. Thus, in a vessel going at 30 feet per second, the jet would have a velocity of 60 feet per second and a head of 56 feet. Static pressure in the pump 24 lbs., the thrust would then be, with the boat moored, equal to 24 lbs. $\times 2 =$ 48 lbs. per square inch of jet area, and, with speed of jet equal to speed of vessel, a thrust of 24 lbs. per square inch of jet would be obtained.

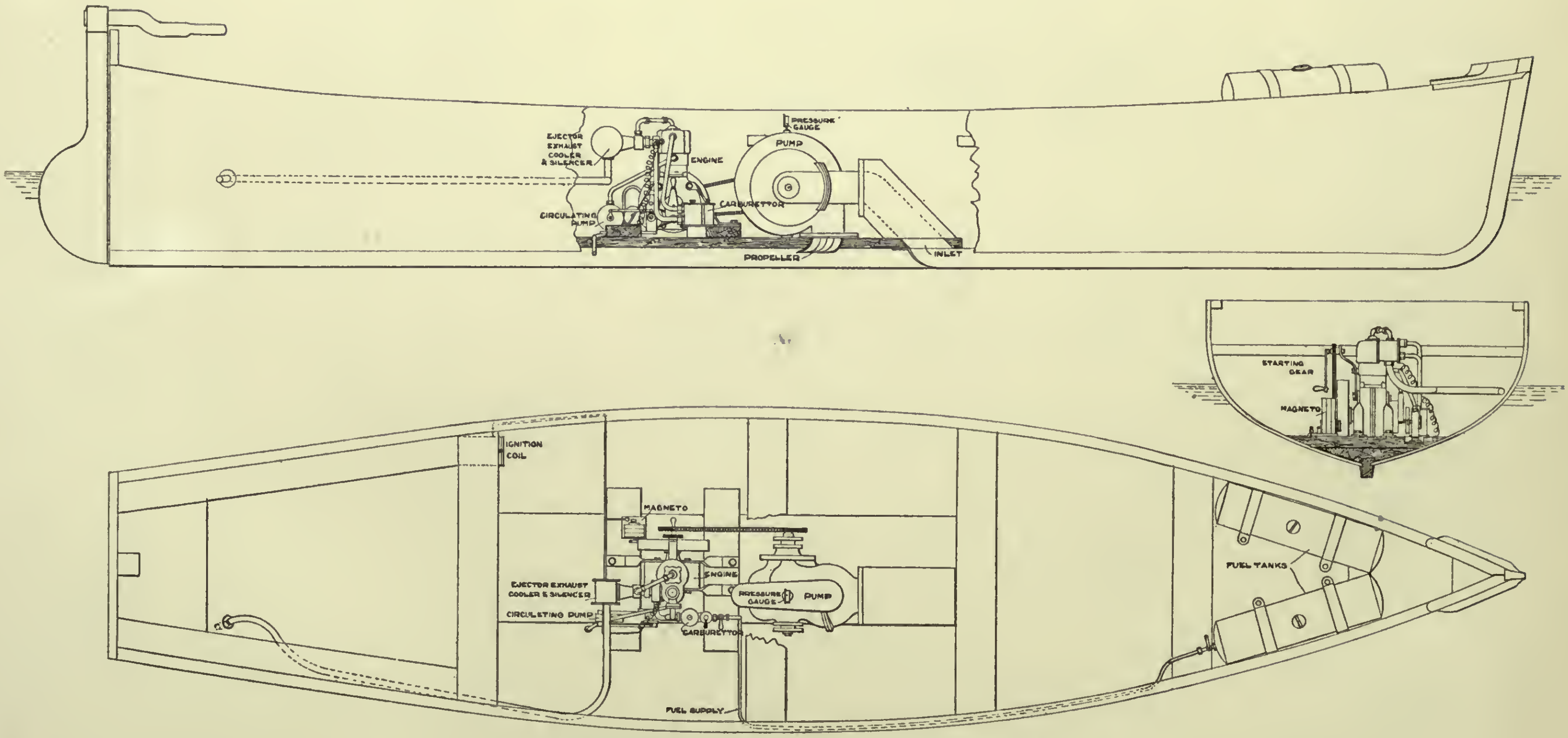

EJECTOR EXHAUST COOLER & SILENCER
PRESSURE GAUGE
PUMP
ENGINE
CARBURETTOR
CIRCULATING PUMP
PROPELLER
INLET
STARTING GEAR
MAGNETO
IGNITION COIL
MAGNETO
ENGINE
EJECTOR EXHAUST COOLER & SILENCER
PRESSURE GAUGE
PUMP
CIRCULATING PUMP
CARBURETTOR
FUEL SUPPLY
FUEL TANKS

FIG. 166.—Elevation Plan and Cross Section of Jet-Propelled Motor Boat.

In Fig. 166 the exhaust ejector is seen with the water branch connected to the top of the cylinder water jacket.

The magneto is shown driven by friction from the fly-wheel, the ignition system being that already described, page 130. A free-wheel starting gear is applied, and a chain wheel drive between the engine and pump shafts.

MOTOR BOAT HULLS

For internal combustion engine-driven boats, the seamless steel hulls seem to possess many advantages, except perhaps for racing vessels. The machinery can be more securely fixed to steel hulls, and they do not alter with the weather or when laid up.

Wooden boats require constant attention and repairs, and water carried in them to keep them serviceable, whereas steel boats require no repairs; so, although slightly dearer than wooden boats at first, pay for themselves owing to requiring no repairs. Wooden boats also, when launching, if they are allowed to strike the ship's side are rendered unserviceable, whereas steel boats have stood this test; moreover, when run ashore in rough weather, steel boats have stood grounding when the wooden boats at same time were broken to pieces.

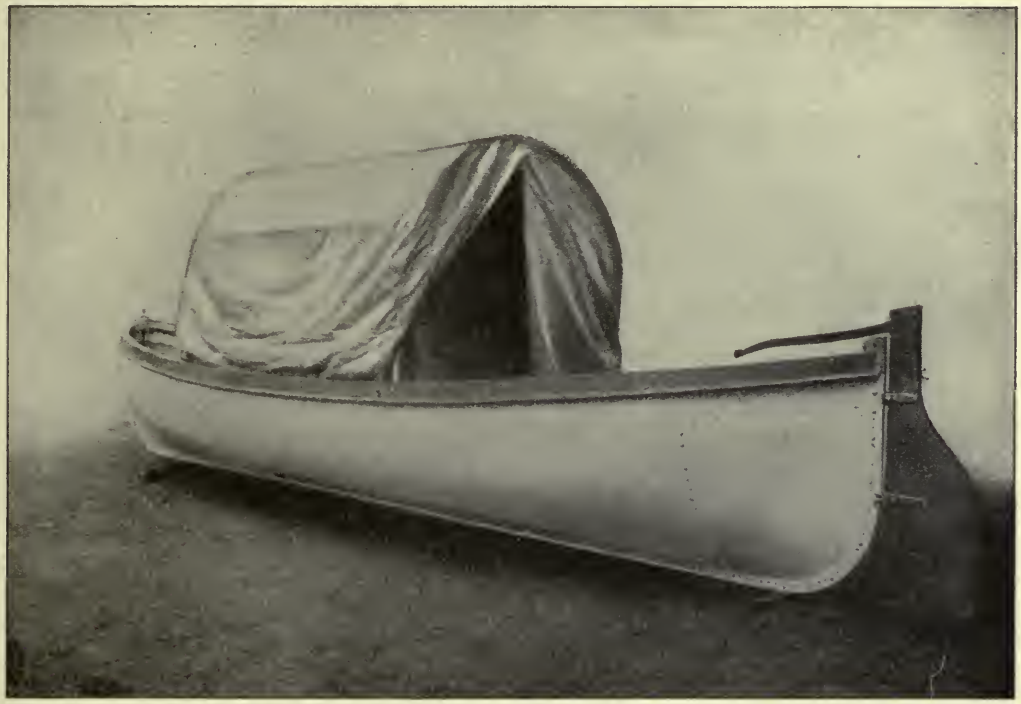


Fig. 167.—Motor Boat with Steel Hull.

These boats are constructed by the Seamless Steel Boat Co., Wakefield.

The hull is formed of two sheets of Siemens-Martin mild steel, pressed into shape and riveted to a steel keel bar, T bulb section forming stem, keel, and stern post. Hull, keel bar, and all ironwork are carefully galvanized. Inside of hull coated with two coats of bitumastic enamel, and outside with two coats of white enamel paint, and varnished. Top strake of teak; gunwale and moulding of American elm; thwarts, side-seats, decks, and floor of yellow pine. Gunwale can be made of steel if desired.

Fig. 167 shows the style of hull for open boats, with a movable cover over engine and machinery.

SOME AUXILIARY MACHINES

One of the drawbacks to steam is the continual stoking required, which includes the cleaning of fires and removal of clinkers and ashes. In vessels consuming some tons of coal per hour this entails some work. In some vessels the ashes and clinker are shovelled out through a port hole in the side—a very awkward job in rough weather. Others have windlasses to lift the ashes in buckets, to be thrown overboard. Most modern ships have steam or hydraulic ash hoists, especially for large-powered boilers. A simple and effective little oscillating steam engine for ash hoists is shown in Fig. 168 by Messrs. Mumford & Co. The cylinders are 4½-inch by 5-inch stroke. Simplicity is the great point in these things: one lever controls the stopping, starting, and reversing.

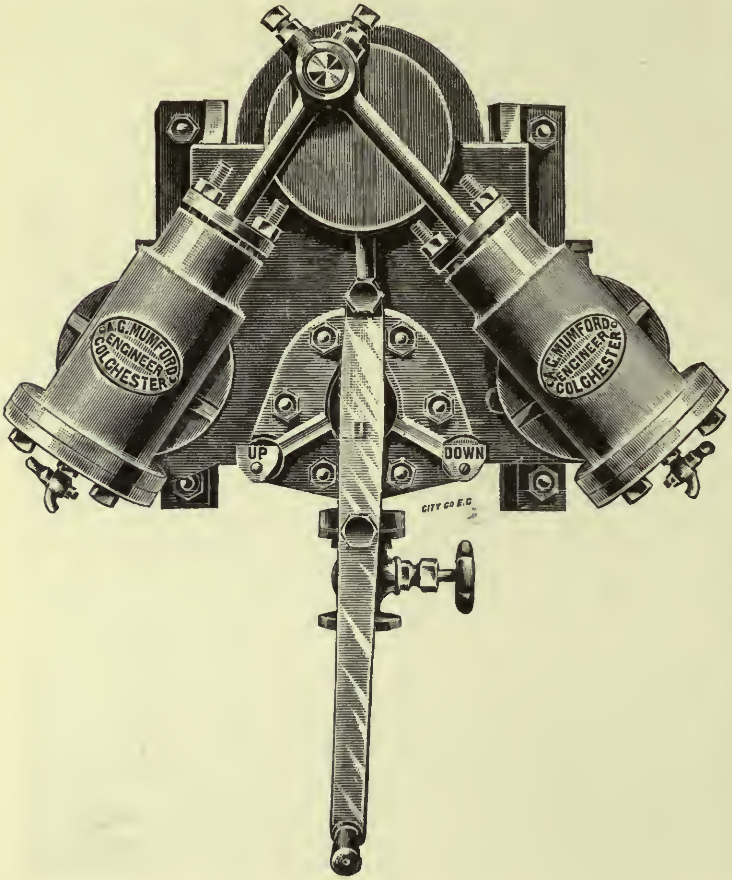

A.C. MUMFORD ENGINEER COLCHESTER
A.C. MUMFORD ENGINEER COLCHESTER
UP
DOWN
CITY CO E.C.

Fig. 168.—Ash Hoist Engine.

ASH EJECTOR

The handling of the hoist buckets for ashes, when lifted by small winding engines, is sometimes difficult. Another method recently introduced is that known as See's patent ash ejector, in which the ashes are blown out through a curved tube by water under pressure from a steam pump.

It is shown in detail in Fig. 169. In the cross section of the ship the ejector pipe is shown, and is inclined at any angle between 55° and 75° from the horizontal. The discharge is well above the water line and inclined slightly downward.

Water pressure is about 200 lbs. per square inch, the 6-inch standard ejector requiring a 3-inch water feed pipe.

The water jet injected into the bottom of the ejector pipe carries with it the ashes, which are shovelled into the hopper W. The upper bend in the ejector tube is made with movable pieces on the back of the bend, in order to be readily renewable. The ashes scrubbing along the bend cause considerable wear, but these blocks can be easily replaced at small cost.

FEED-WATER FILTER AND HEATER

The economy of fuel and the prevention of leakage by the introduction of hot feed water has led to the general adoption of feed heaters, and, as the air pumped into the boilers along with the feed is now generally recognised as a fruitful source of corrosion, an arrangement for extracting this air has also been found to be of great advantage.

The risk of overheating and collapse of furnaces caused by the introduction of oil or grease into boilers, especially those worked at the high pressures now in common use, as well as the pitting action which the grease sets up on plates and tubes, has made a feed-water filter a necessary adjunct to all well-equipped boilers.

The filter (Fig. 170) of Messrs. Kincaid & Crockett meets the requirements to some extent.

The clinker filter and feed heater is offered as a simple and efficient apparatus for combining the three important operations of separating all grease or extraneous matter from the feed water, raising its temperature, and extracting the air.

The filter has been designed to avoid the use of cloths or hoods, cocoa-fibre cylinders, or such like materials as filtering mediums. The constant renewal or cleaning of these constitutes not only a source of continual expense to owners, but of trouble and annoyance to engineers. Besides, should the stock of these on board run out during a voyage, the filter is rendered useless.

With this apparatus the filtering material costs nothing, and is always available, consisting simply of broken clinker or slag from the furnaces, passed over a sieve, and well washed to free it from grit and dust. After use it is emptied on the stokehold floor, and a fresh quantity put into the filter case. The filter case is made of light galvanized steel, and, being simply held in position by the outer lid of filter, can be removed and replaced in a few minutes.

The suction area through this case is very large, and, the water having to pass between its inner and outer shells and down through the outer mass of the filtering material, all grease and dirt are effectually absorbed.

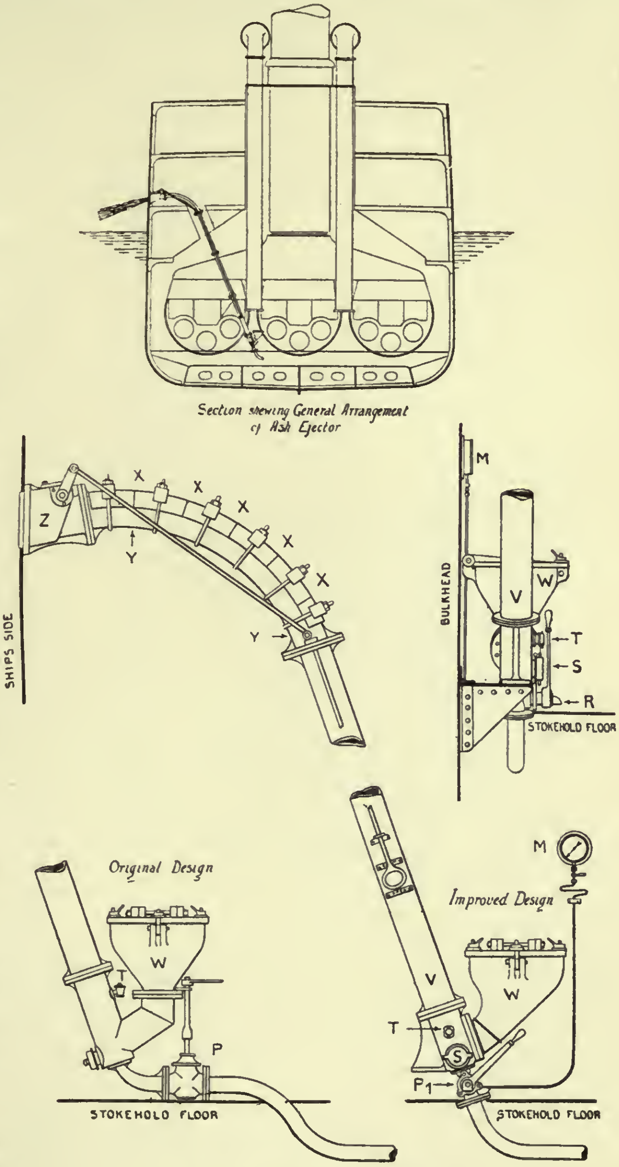


FIG. 169.—Ash Ejector.

Provision is made for separating and carrying off to the condenser any free air that may be brought into the filter along with the water. The feed heater, which may or may not be combined with the filter, consists of a series of pipes in the outer casing, of horse-shoe form, supplied with steam from any convenient source. The feed water may by this means be raised in temperature to 200° after it is filtered, and the air held in suspension is thus expelled and conveyed back to the condenser, instead of being pumped into the boiler, as it would otherwise be, to cause corrosion of the plates and tubes.

It will be seen that, though this filter and feed heater may be attached to either side of the feed pumps, it is specially designed to be fitted on the suction side, where there is no risk of damage to pumps or pipes when the engines are racing or the filter is allowed to get choked, a danger ever present with filters on the discharge side. Unless specially ordered, the filters are only made for suction side of pumps.

All clinker filters are fitted with cocks or valves, so arranged on outer casing as to form a bypass for the feed water when the filter case is being changed. In Fig. 170 the upper cock is connected to the feed pump, the lower one from the hot well. There is a bypass between the two cocks, so that feed may be direct from hot well when desired. The same firm make a separator for the exhaust steam, which passes through it on its way to the condenser. It is shown in Fig. 171. The spiral vanes round the cone in the exhaust pipe cause a centrifugal motion of the steam, by which any oil, grease, and dirt carried with the steam through the cylinders are thrown against the sides of the pipe, running down into collector. From this they are drained into a filter, which retains all extraneous matter. The inside of filter is connected to bottom of condenser, and the condensed steam is returned in an absolutely pure state.

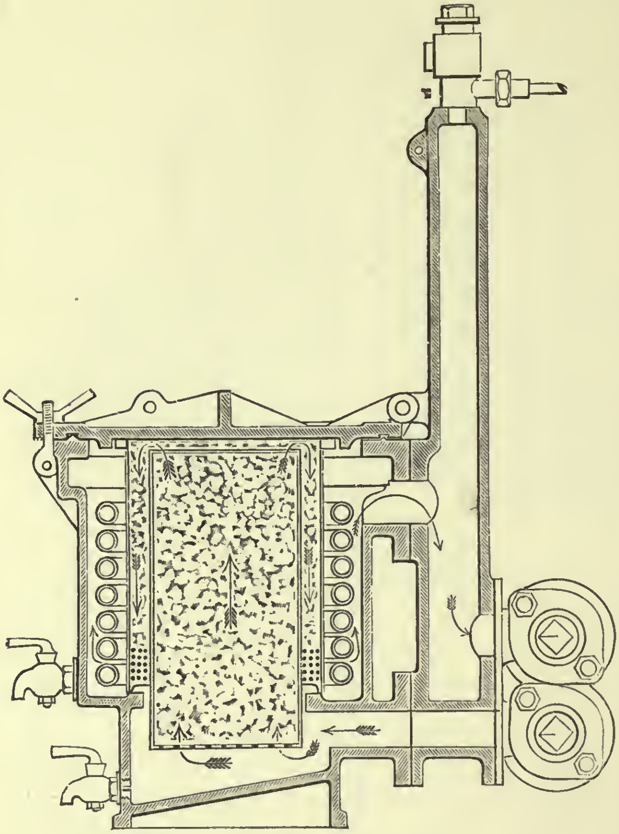


Fig. 170.—Feed-Water Filter.

All the exhaust from auxiliary engines may be passed through it at the opening shown in Fig. 171.

THE GYROSCOPIC EFFECT ON VESSELS

These effects are well known to affect the steering and working of paddle steamers, the paddle wheels acting as fly-wheels. Paddle steamers roll less than screw steamers, the gyroscopic effect of the paddles tending to maintain a level axis for the wheels. The effect may also be seen when a paddle steamer is turned by the rudder: if the vessel is turned to starboard the vessel lists to port, and *vice versa*.

These effects have been carefully studied by Herr Otto Schlick, and the results embodied in a paper to the M.I.N.A., 24th March 1904, from which we make some extracts.

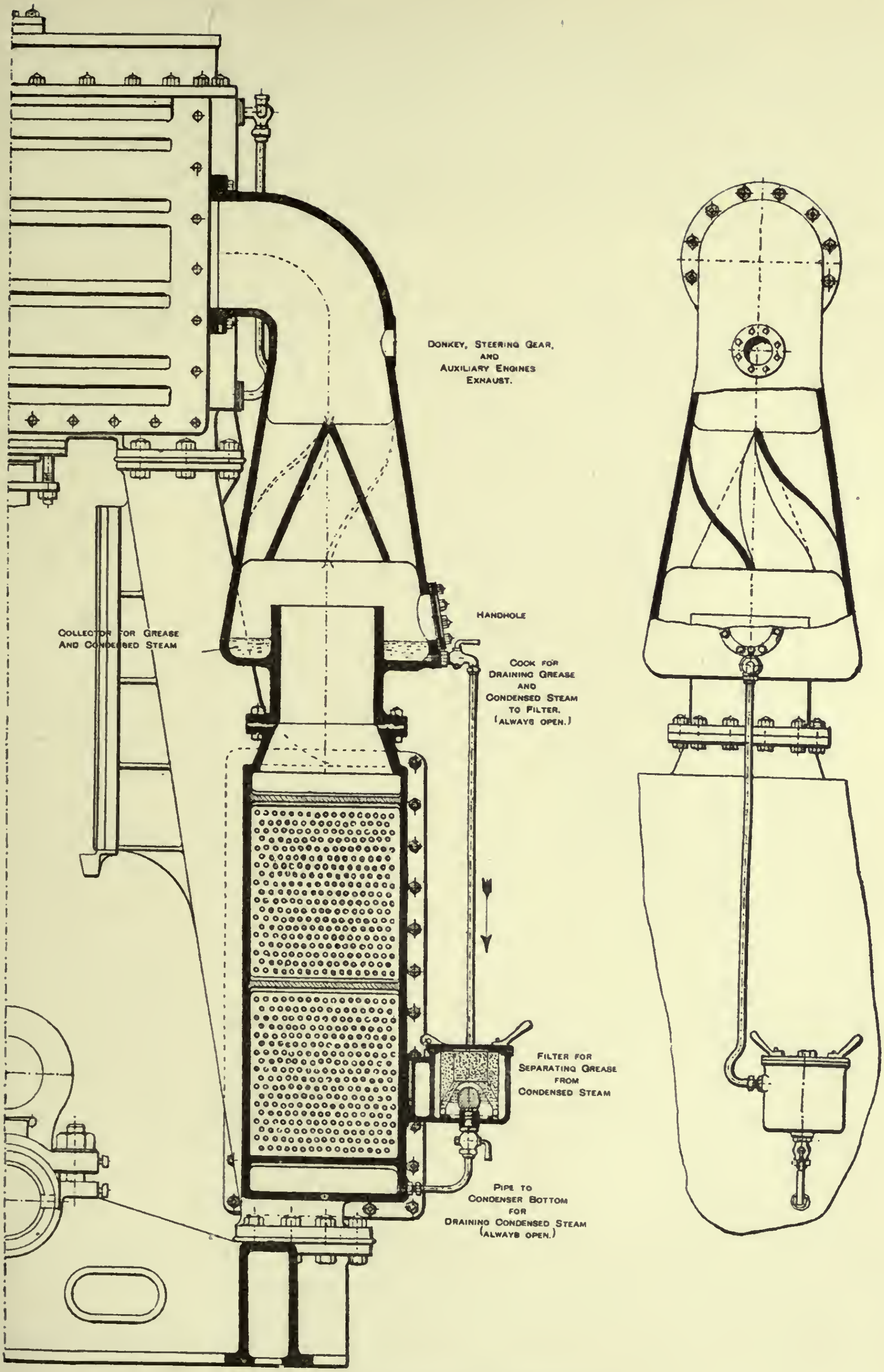

DONKEY, STEERING GEAR, AND AUXILIARY ENGINES EXHAUST.
HANDHOLE
COLLECTOR FOR GREASE AND CONDENSED STEAM
COCK FOR DRAINING GREASE AND CONDENSED STEAM TO FILTER. (ALWAYS OPEN.)
FILTER FOR SEPARATING GREASE FROM CONDENSED STEAM
PIPE TO CONDENSER BOTTOM FOR DRAINING CONDENSED STEAM (ALWAYS OPEN.)

FIG. 171.—Exhaust Steam Separator.

He constructed a model, as shown in Fig. 172, which consists of a fly-wheel FF pivoted on centres in a ring. This ring is pivoted on centres at right angles to the first centres, and are marked PP, carried by a fork on a pendulum pivoted at N. The ring is weighted at S, so that it returns to the upright position after being deflected on the centres PP. If the pendulum be set swinging without the fly-wheel being made to rotate, it will be found to move to and fro with a certain definite period. The frame in which the fly-wheel is borne may first be allowed to move as easily as possible, *i.e.* with a minimum of friction. If the fly-wheel be then set spinning and the pendulum receive a push, the latter will, in the first place, show a considerably increased period of swing.

The fly-wheel oscillates with its frame during the swings of the pendulum with a so-called phase difference of 90°—that is to say, the swings of the axis of the fly-wheel keep lagging behind those of the pendulum by a quarter of a swing. While the pendulum is passing its central (vertical) position, the axis of the fly-wheel will show its greatest inclination; and when the pendulum is in the outermost position of its swing, the axis of the fly-wheel stands exactly in its middle position. The amplitude, or extent of the swing, of the pendulum will, as theory tells us, not be influenced thereby, but will remain exactly as great as before. That this is the case will also be readily apparent, since no consumption of energy takes place in the apparatus, the period only being influenced by the increase which takes place in the swinging mass.

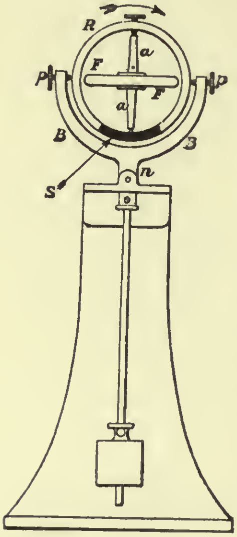


Fig. 172.—Gyroscopic Experiment.

Were it possible to fit a fly-wheel of this kind, able to swing in its frame without experiencing friction, into a vessel, this would be advantageous in so far that, to begin with, the rolling motions would become slower, and therefore less unpleasant; and then, on account of the great difference thus produced between their period and that of the waves, they would cease to be of any consequence. The rolling motions of the vessel would then become considerably less in extent. If the frame which bears the fly-wheel be screwed tight on the model so that it can no longer turn, the effect hitherto produced by it will cease, and the pendulum will swing with the same period as it would if the fly-wheel were not rotating.

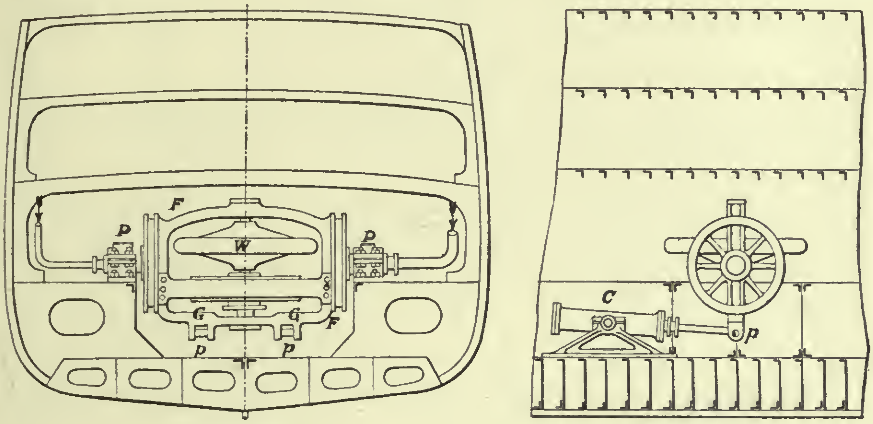
It will readily be seen that the effect produced upon the swings of the pendulum by the rotating fly-wheel can be of greater extent only so long as the plane of the frame bearing the fly-wheel remains approximately vertical.

If the axis of the fly-wheel be inclined at an angle to the vertical, the moment thus produced, acting against the motion of the pendulum, will be proportional to the value of cos of the angle. Should the axis of the fly-wheel momentarily become horizontal, a position which with a pendulum in violent motion it may almost reach—that is to say, should the angle equal 90° and cos equal 0—the influence of the fly-wheel will disappear altogether.

Since, as already stated, there is a phase difference of 90° between the swings of the pendulum and those of the axis of the fly-wheel, the gyroscopic influence on the pendulum must be least in amount when it is passing the middle position, *i.e.* at the very position at which it has its greatest angular velocity, because at the same moment the inclination of the axis of the fly-wheel is at its greatest, while the velocity with which it is changing its inclination has become very small or vanished altogether. When, on the other hand, the pendulum has reached its outermost position, and is changing the direction of its motion, thus for an instant reaching a state of rest, the axis of the fly-wheel then proceeds with its greatest angular velocity through the middle position, the fly-wheel thereby exerting its greatest influence. It will thus be evident that the conditions for the exertion of the greatest possible influence of the gyroscopic action of the pendulum are not present here. In order that the motion of the pendulum may be effectively influenced, the oscillation of the frame with the axis of the fly-wheel will have to be reduced in a suitable degree. In the model illustrated in Fig. 172 this may be most simply effected by tightening the screws to a suitable extent, so that they act as a brake on the motion of the fly-wheel. The swings of the fly-wheel frame are thus reduced in extent, and the phase difference between the two swinging movements here described now becomes less than 90°.

If the experiment be made of setting the pendulum swinging with the brake thus applied to the fly-wheel frame, a very different phenomenon will be observed. The pendulum will indeed still swing with a very considerable period, but the maximum angle attained becomes considerably reduced with each successive swing, so that a state of rest is reached even after two complete swings. In scientific language, the oscillations of the pendulum experience a damping, in that the energy stored up in it is destroyed by the friction applied to the fly-wheel frame.

The gyroscopic action of a rotating fly-wheel has in the above been illustrated as applied to a pendulum. It will readily be seen that it may be applied in a similar manner to retard the rolling motions of a vessel. In Fig. 173 the vertical axis of the fly-wheel W is set in bearings in a large frame FF, which can turn on the journals PP, about a horizontal axis lying at right angles to that of the vessel. It may be made to rotate rapidly by means of an electromotor or a steam turbine.



Elevation. End View.

FIG. 173.—Gyroscopic Machine for Ships.

Fitted to the frame is a journal *p*, which is connected with the piston rod of one or of two hydraulic brake cylinders C, and, by the throttling of the area of the communication tube, enables the swings of the frame FF to be braked at will. The frame is ballasted at its lower side by a weight G, as was done on the pendulum model, or the journals PP may be fitted somewhat above the position of the centre of gravity of the whole frame. As soon as any outside influence begins to heel the vessel over in a direction at right angles to its length, the fly-wheel frame will incline considerably, with the result, as in the case of the pendulum model, that moments are produced which not only render the oscillations of the vessel considerably slower, but also very considerably reduce their extent. But these two conditions are exactly the ones which alone are calculated to destroy the rolling motions caused by the waves. A vessel fitted with the appliance illustrated would, according to this, only be subject to insignificant rolling motions. On the other hand, the frame, with its fly-wheels hung up within the vessel, would swing violently to and fro.

In addition to the hydraulic brake, it will be necessary to fit one or two powerful band brakes, which will enable the fly-wheel to be held at large angles.

Henry Bessemer, of steel fame, spent large sums in experimenting with a vessel, in which he attempted to swing the saloon so that it remained at rest when the boat rolled and pitched; but, owing to the imperfect knowledge of gyroscopes at that date, and other difficulties, it did not reach a practical end. The great point made clear by Schlick is that there must be two motions at right angles to each other. The axis of the fly-wheel must be allowed to swing in a plane at right angles to the motion to be resisted, and this swing must be resisted by some means. That simple pendulum experiment teaches more in a few minutes' study than all the pages of formula which have been written on the gyroscope.

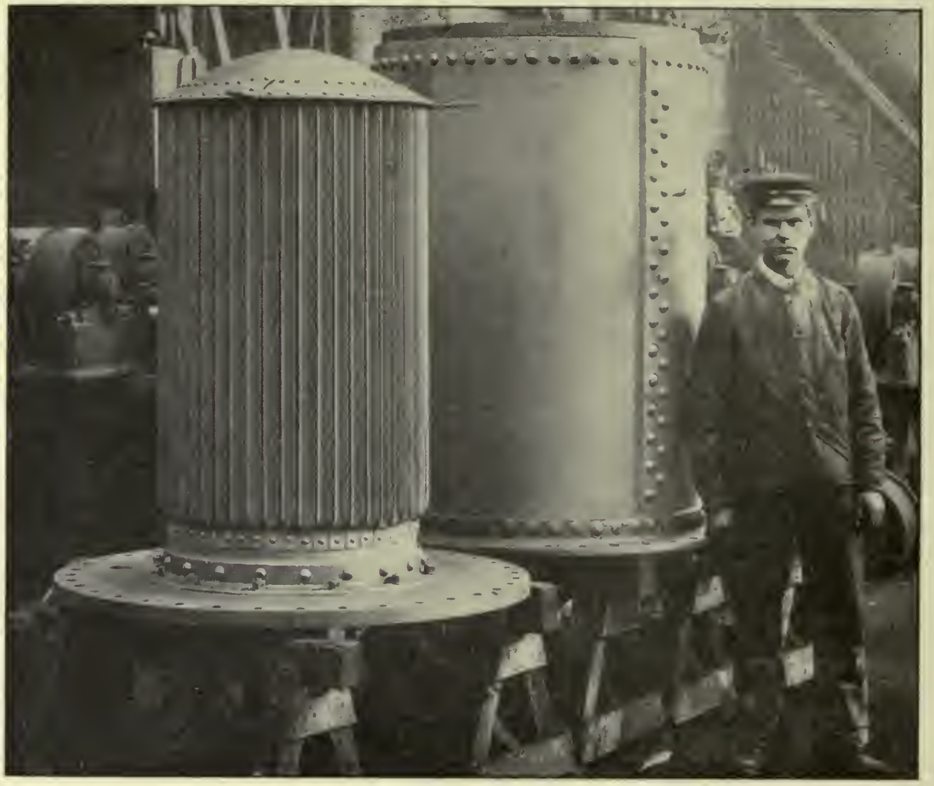


Fig. 174.—Water Separator.

PROFESSOR WATKINSON'S SEPARATOR FOR STEAM

A novel separator has been brought out by Professor Watkinson, who has furnished drawings and a brief description, from which the design and construction can be gathered. The photo (Fig. 174) represents a large one in course of construction; the inner part is shown alongside of the outer shell; the workman beside the parts by comparison give an idea of the dimensions. Fig. 175 is a sectional plan showing the angle iron bars, and Fig. 176 is a sectional elevation of the separator.

The separator has proved to be exceedingly effective for removing water from high-pressure steam, and it will be equally effective for removing water and oil from exhaust steam. The separation of the water from the steam is effected by angular strips, arranged at very small distances apart, so that the steam is divided into thin sheets as it flows between the strips. The water drains down the angles into a trough at the bottom, from which it is drained through a steam trap. There are two concentric belts of angles in each separator, and the angles in one belt break joint with those in the next belt.

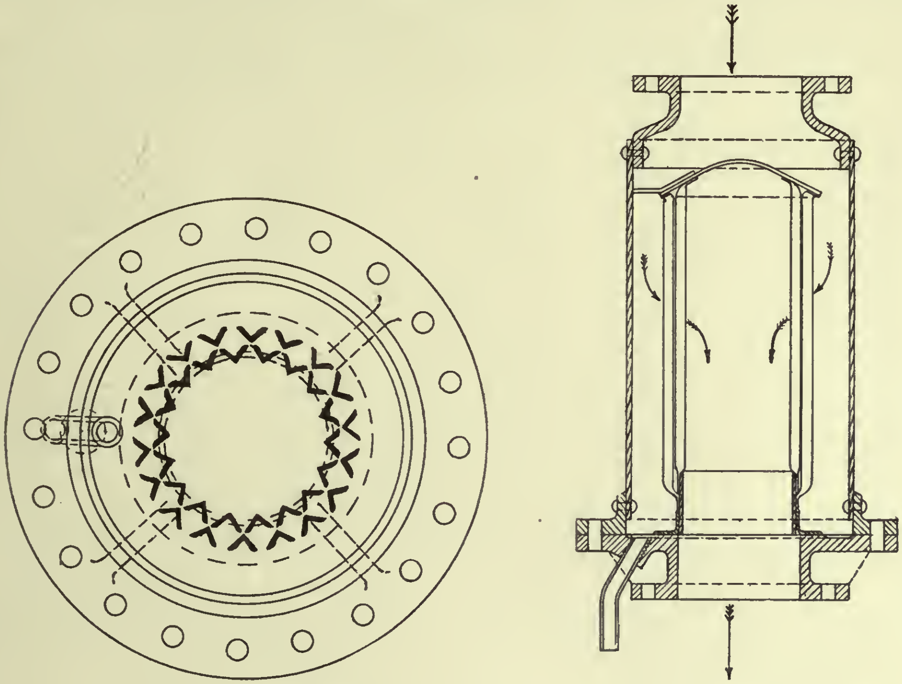


FIG. 175.—Sectional Plan. FIG. 176.—Transverse Section.

Water Separator.

The idea of the separator is that the water in the steam being heavier is thrown against the angle bars, to which it clings and trickles down to the bottom, while the gaseous steam passes along freely through the slits.

PRESENT DAY MARINE ENGINE PROGRESS AND THE FUEL QUESTION

In concluding the marine engine section of this work it is interesting to note that the spirit of progress shows signs of revival among marine engineers. The turbine has obtained a footing, not among small craft, but in the largest marine work going, and is bound to make for improvement—so far as the mere exchange of one steam motor for an improved steam motor can improve the steamship. As this is being written, a Royal Commission inquiring into our coal supply has issued a report, in which figures are quoted putting a very rosy view before us as to the amount of coal still available in the British Isles. The coal available at depths of less than 4000 feet, and in seams more than one foot thick, is estimated at 100,914,668,167 tons. The fineness of this estimate is not a little suspicious. 100,000,000,000 tons is most likely quite as close an estimate. Then, the geological committee on the Commission venture to estimate that coal not yet discovered or in unproved fields may amount to 39,483,000,000, tons, an estimate not quite so close, as it does not go beyond 3,000,000 tons more or less. The two estimates show about 140,000,000,000 tons of coal still to be worked. There may be good grounds for basing these estimates upon, but they are not obvious from the inquiry. Even granted the quantities are approximately correct, we have no warrant to count upon the geological estimate at all, and the proved estimate of 100,000,000,000 tons includes a vast quantity of coal which will be very expensive by the time it reaches the surface. A one foot seam at half a mile depth will be dear coal indeed. The point which interests the engineer is not the quantity of coal at less than 4000 feet depth and over a foot thick, but the quantity available at present prices, a question the Commission does not solve. The hope that the increasing demand for coal will not continue is one doomed to disappointment. All the advances in mechanical and electrical sciences tend to increase the consumption of coal. Electric tramways, railways, and electric lighting all consume huge quantities of coal; far more than is generally supposed.

In the steamship the coal consumption per horse-power-hour has been steadily decreased by improvements not only to save the coal, so much as to save the space and weight of its carriage on board; and before very long the coal consumption on a ship now consuming 2 lbs. per horse-power-hour will, by using gas engines and gas producers, be reduced to something below 1 lb. per horse-power-hour; but, at the same time, ships are growing in size and power and in numbers, so that with all the improvements the total quantity of coal consumed must increase.

The naval fleets of the world are growing in power and numbers: coal is their constant demand. Iron and steel structures are growing in numbers in place of wood and stone: every ton of steel and iron represents half a ton of coal consumed. The rate of increase of consumption has been, for home purposes, about 2½ per cent., and 4½ per cent. in export. The Commission expect a decrease in consumption, but here again there are no grounds to support any such expectation. Until the supply of coal becomes shortened and the price rises there will be no abatement of the increasing demand. The annual output is about 230,000,000 tons at present, but no engineer takes this as anywhere near the maximum demand for coal. At the present rate of progress in railways, steamships, battleships, electrical engineering, tramways, iron and steel buildings, all over the world, the demand for coal must go on increasing.

Looking to the most reliable figures, it is safe to say that for fifty years to come there will be no great increase of the price of coal to check the increasing demand, but long before the half of the proved available coal is used up the cost of coal in Great Britain will be at a price which will interfere with a great many manufactures only possible at present with cheap coal. The whole question of most interest is not how much coal is there? but how much cheap coal is there available? The Commission, very wisely, bluntly state that there is no substitute for coal. In this they are doing good, in sobering down the enthusiasm of the cranks who confidently rely upon science to help out in any case of need.

Whether it is right or wrong to export our best coal in huge quantities is not a question to be discussed here, but the commissioners have been convinced that the export is harmless, and may be rather encouraged. A good deal of the evidence given on this point is, however, not entirely disinterested. As a whole, the report deals too much with commercial aspects of the subject, and does not carry much weight as a scientific treatment of this all-important subject to every one interested in prime movers.

When those hysterical writers on popular science rave about the marvellous progress of science, they forget that the finest steam engine in the world wastes about 90 per cent. of all the coal used to fire its boilers. When they are amazed at the mysteries of liquid and solid air, radium, wireless telegraphy, electric light, and electric motors and tramways, it is not made clear to them that all these things are only made possible by the abundance of cheap coal, tons of which are consumed in their production and working. Physical, chemical, mechanical, and electrical sciences progress slowly and surely, and it is to these sciences, with the aid of mathematical reasoning, that the world is indebted for all its material progress. But it is only when the results of the researches in these sciences are brought into practice by the inventor that the real movement in progress is made. The production of efficient prime movers is the most important of all problems in science; and as coal is the only cheap fuel, its economy is of the utmost importance. The internal combustion turbine or engine is a step above the steam engine; beyond the gas engine we at present cannot see. Dimly we can conceive a conversion of coal energy directly into electrical energy, but the most acute minds cannot pick up a clue to the solution of the problem. We know some things we must not do in the matter, such as that there should be no heat production in the process. When energy takes the form of heat, it has been degraded so low that only a small portion can be recovered to do work. The great problem of the future is this: to discover a process for converting the energy of fuel into electrical energy before it falls to the state of heat energy. That discovery would work miracles on this globe far more marvellous than anything recorded in the past.

A great deal has been said and written about the education of engineers, so that they may help in the movement of forward progress. There are abundance of schools, colleges, and training institutions for an education of a kind for those who can pay for it; and there are ample bursaries and funds to assist those who cannot pay for their education. These are, however, in most cases appropriated by those who could very well pay. What is wanted in this country is some system of education whereby the artisan, mechanic, and other apprentices in the skilled crafts should be enabled to obtain, without expense, a sound grounding in physical science, chemistry, mechanics, mathematics, taught in a thoroughly attractive manner. It is from this class the inventor as a rule springs, and from this class many of the leaders in industry are drawn despite the disadvantage of their early youth. The great Faraday was a bookbinder's boy; Gramme, the dynamo inventor, was a carpenter; Edison as a boy sold newspapers; Watt was educated somehow, but had none of the advantages of the students and professors of his day; and so on, we could make a long list of this class. My own observations, extending over thirty years in engineering, convince me that far too little attention is given to the scientific education of the workers. Many of them, no doubt, do not want it, but many of them do want it and cannot get it.

The old science and art classes under the South Kensington régime did thoroughly good work among this class some twenty-five to thirty years ago, and many eminent men in the industries of Great Britain obtained their first start through the scientific knowledge gained at these early science schools. The technical colleges and schools are only helpful to those in a position to help themselves, and the curriculum is in few cases the correct thing. The great defect of all of them is that they attempt to treat every student alike. All students are passed through the same courses, whether agreeable to them or not; certain subjects are prescribed and must be taken, and far too many subjects are taken up at the same time. Fancy a young student preparing for an examination in eight to ten subjects simultaneously. There is no lack of money, schools, and professors for educating engineers; but the whole educational machinery and systems are badly directed, the money misspent. The science schools exist more for the teachers' than for the students' benefit.

These remarks on the education of engineers are called for, in view of the fuel question, because only a few weeks before the appointment of the Coal Commission, an eminent professor of engineering proposed that a large sum of public money should be placed at the disposal of two other eminent and already very wealthy professors in order to investigate and bring out improvements in the utilisation of fuel for prime movers. Now, the same two scientists have for about half a century had at their disposal all the resources of large laboratories perfectly equipped, and unlimited funds for research. The results of their labours would not warrant one to suggest that they would evolve any invention of value, no matter how much money was placed at their disposal for the purpose. The proper thing to do in this matter would be to offer facilities and money assistance to any inventor, professor or not, who has a scheme and is desirous of working it out. We provide laboratories and assistance for raw students to work in, at a time of their life when they are not able to make much profitable use of their opportunities ; but the experienced engineer who has arrived at years of wisdom and knowledge has no assistance, no laboratories, or anything provided to carry out any important invention or research. He has to do all he can at his own expense. There should be public laboratories in every large town, open to engineers with ideas. There are at present two or three private institutions where an engineer can get room and apparatus for working out ideas ; but the expense excludes the very men who require them most. The cost of public laboratories would not be great: the results would be very great, and more valuable than those arising from free libraries.

LOW ELECTRIC PRESSURE PETROL MOTOR IGNITION

With careful insulation and properly protected plugs the high-pressure spark ignition for internal combustion engines is satisfactory; but if the insulation develops any faults, the high-pressure soon finds them out and the spark fails. Water getting into a magneto or coil or plug also causes failure, sometimes in most awkward places. Certainty of ignition is of more importance in a boat than in a motor car : failures and stoppages on a motor car are mostly of little consequence—often merely a laughing matter. They are never so in a boat: a stoppage from any cause is always a serious matter in a vessel. Reliability is of first importance.

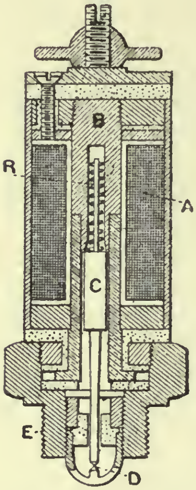


Fig. 177. — Caron Magnetic-Ignition Plug.

Low-pressure ignition is less liable to failure from faulty insulation or from water getting into the system. It is therefore of interest to note that several low-pressure arcing ignition plugs have been introduced recently, offering a means of simply adopting low electric pressure.

The principle of the low-pressure plug is the same as that of the trembler coil. There are two sparks produced in the high-tension coil—the secondary spark which occurs at the plug by jumping the gap, and a primary spark at the trembler which we try to minimise. It is this primary spark which is used in the new low-tension plugs, and the secondary high-pressure circuit is altogether suppressed. We simply put the trembler into the cylinder and fire by the spark it produces.

The device is clearly shown in Fig. 177, a section of the Caron plug, the whole apparatus not being much larger than an ordinary plug, whose place it takes in the cylinder. The rod C, by which the internal break is obtained, has a to-and-fro motion. When the circuit is closed at the contact maker on the half-time shaft of the motor an electrical current flows through the coil A, magnetising the soft iron core ; the latter in turn drawing up the rod C from the point D, a huge spark, due to the self-induction current, taking place when the rupture is made. A light spring around the rod returns the latter to its normal position, resting on D, when the external contact is broken. The only part subject to wear is the point D, which, as in other arrangements, is made renewable. In this and similarly actuated plugs the breaks at D are very small and rapid, as they are in all tremblers.

The Zubalof plug is a more elaborate device, and acts more as a relay than as a trembler. There are two coils: one acts as the self-induction coil, which causes the spark at the break. The other coil simply opens and closes the break positively ; in fact, does what is effected by rods and levers in low-pressure ignition actuated mechanically.

Fig. 178 gives a general view of the Zubalof arrangement, which is being introduced by M. Beaupied of Paris. As will be seen, the apparatus is so arranged that it can be fitted in place of the ordinary high-tension sparking plug. Referring to the sectional view (Fig. 179), it will be noticed that the central rod of the plug, by means of which the internal break in the electrical current is obtained, has an oscillating movement instead of a to-and-fro motion. The rod or lever is supported at the point of its centre of gravity on a spindle S, from which it is insulated by means of mica. The lower end D of the rod carries a hammer, fixed to it by means of a pin. The hammer, rod, and spindle are of nickel, while the end O of the rod is mica insulated. The electrical current, which may be furnished either by an accumulator, dynamo, or magneto, is divided into two portions. When the external break in the circuit is closed—that is to say, when contact is made on the contact maker on the half-time shaft of the engine—the current flows through the coil B; at this moment the hammer D, or rather the lever M, is attracted towards N, and, turning on its spindle, causes the hammer D to make contact with the block C. This done, the coil B^1 in turn becomes magnetised, as a part of the current from the battery passes through the coil B^1, the lever, hammer and block, which are in series with it. The engine continuing to run, the external contact on the half-time shaft is broken; the blade being on the insulated portion, current ceases to flow to B. The coil B^1 only is now magnetised, and attracts in turn the lever M, causing the hammer D to leave the block C suddenly, a large spark due to the extra current taking place between the two parts. The contact maker on the engine can, of course, be advanced and retarded in the usual way. This plug has the advantage over the mechanically opened break that there is no stuffing gland to keep tight.

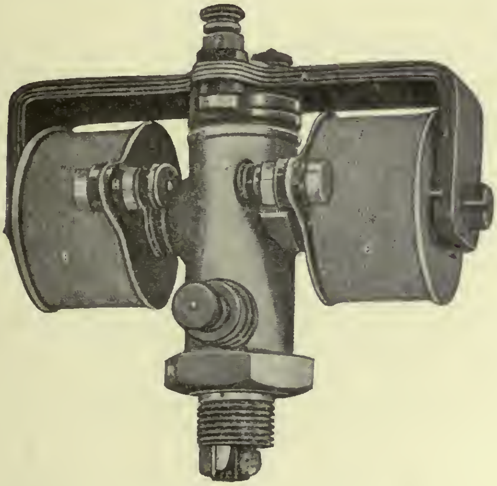


FIG. 178.—Zubalof Magnetic-Ignition Plug.

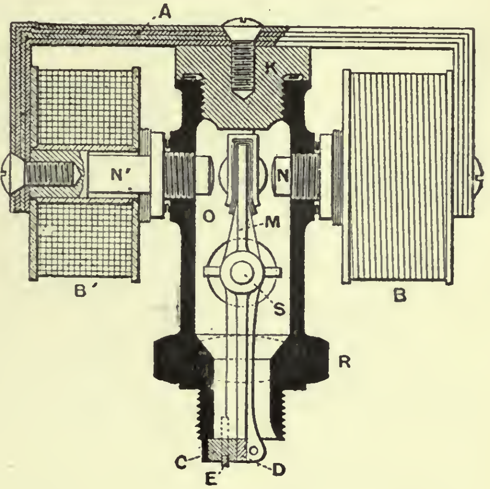


FIG. 179.—Zubalof Plug. Transverse Section.

MOTOR BOAT HIGH-TENSION SPARKING IGNITION

For motor boats it is of importance that the leakage of the sparking current should not take place along damp insulators or wet plugs. With ordinary high-tension sparks from magnetos and coils the leakage often causes misfires; and this is one of the reasons why the author objects strongly to the introduction of distribution wipe contacts on the high-tension circuit, they are so liable to leakage.

The Lodge high-tension ignition system, already described in Volume III., page 35, utilising the B spark between two outer coatings of a Leyden jar, is claimed to have the advantage that the spark currents will not leak readily from the circuit. If the whole arrangement is carefully carried out according to the specification, that is true. The insulation from earth of both jars and their connections is of great importance.

A similar immunity from leakage can be conferred on the circuit without using any B spark, but by still employing the ordinary A spark or secondary spark, and attaching a small capacity condenser to the secondary circuit of the induction coils : this arrangement of the author's sparking ignition coils with the magneto generator is shown in Fig. 180 in diagram. It is the usual system of induction coil connections with a magneto generator M, the condenser C_2 being a small Leyden jar across the terminals of the high-pressure coil D. This condenser renders the current one of a high frequency oscillatory character, which, owing to its magnetic inertia, refuses to deviate from the circuit.

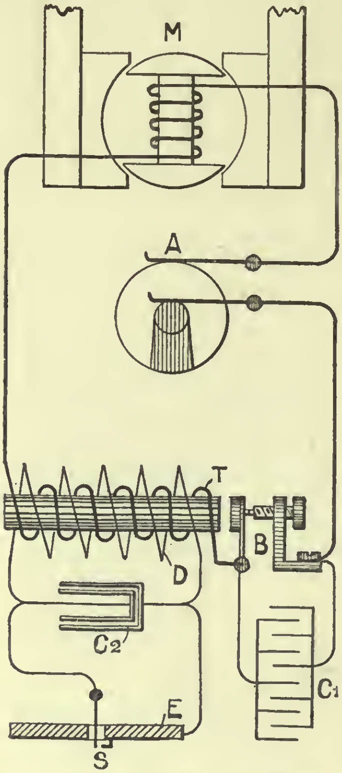


FIG. 180.—Condenser Ignition System.

For small boats, electric ignition employing magneto generators is likely to be the best system, as it works at moderate compression in engines of small weight with satisfaction ; but for large oil engines spontaneous ignition, due to high compression and heat in the combustion chamber, is more likely to prevail in the future.

ELECTRIC PRIME MOVERS

On first thoughts one is inclined to merely state that there are none of sufficient importance to write about. There are, however, some of considerable scientific interest. They are of little importance, because the power they give costs about ten times that given by steam engines ; hence at present they are of small value commercially, and only used for some very special purposes, where the amount of power required is small and the cost of secondary consideration.

Electric motors there are in plenty, giving power at about one penny per horse-power-hour, but all of them are driven from steam or gas engines producing the electricity through dynamos, and this mechanically produced electricity it is which works the motor. The electric motors now in use are not the "prime movers."

The ideal electric prime mover requires no boilers nor engines nor dynamos. The electricity is generated by direct consumption of the fuel, and passes direct to the motor.

The direct production of electricity is a chemical process, and unfortunately the best available fuel is a metal, zinc and certain chemicals, such as sulphuric acid, nitric acid, chromic acid, sal ammoniac, and other active materials made up into cells called primary cells, the many varieties of which can be studied in special books on the subject. Most of the cells in the market are of small size, designed principally for telegraphs, telephones, and electric bells, for which purposes only exceedingly small power is required.

For power purposes batteries of cells must be large with large elements and plenty of room for solution. There are only four types of cells worth considering at all from prime mover points of view—

The two-fluid chromic acid cell.
The two-fluid Daniells' cell.
The single-fluid Leclanche cell.
The Edison-Lalande single-fluid cell.

When zinc or any other material combines with the fluid in a cell one result is a liberation of hydrogen, which appears at the plate or rod in the cell opposed to the zinc. This hydrogen coats this plate or rod or electrode and greatly reduces the output of the cell. Various means for removing this gas mechanically have been tried without much success, but even if it did succeed, the hydrogen, which represents so much fuel, is lost. In some two-fluid cells a fluid is provided at this electrode which combines with the liberated hydrogen and gives up electrical energy in doing so; consequently these cells give higher electrical pressure. The first cell in the above list belongs to this class. Its electromotive force is about two volts, due to the combination of zinc in sulphuric acid solution, and the combination of hydrogen in the chromic acid solution.

The best cells of this kind in the market are those made by the Silverton Company, and shown in Fig. 181, which represents six cells joined up to give twelve volts in series. The outer jars are each of five quarts capacity, and contain four plates of carbon cast into lead connections. A porous pot contains the zinc plate, and separates the chromic acid solution from the sulphuric acid solution. It will give five ampères for twenty hours at about ten volts, or fifty watts for twenty hours, that is, exactly one Board of Trade unit of electricity, which is sold in many public supplies for power purposes at twopence. Now let us see what this unit costs from this battery of six cells:—

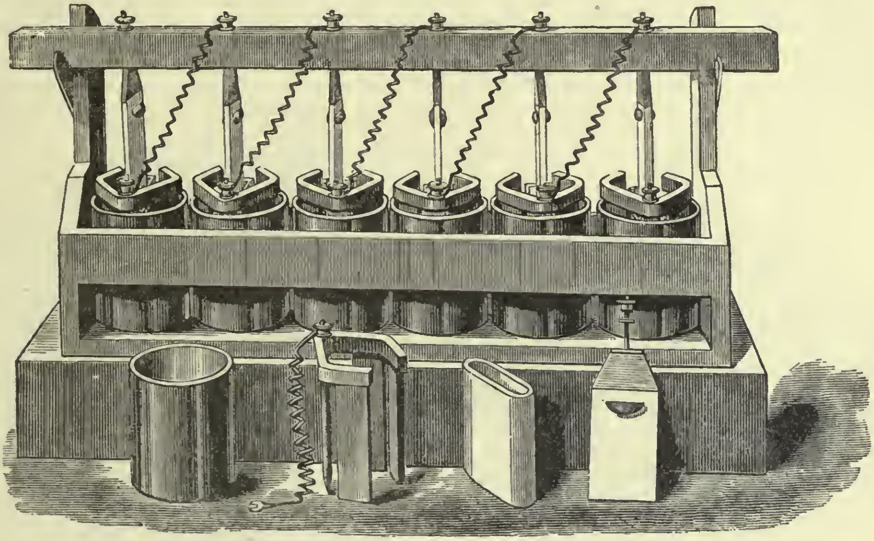


FIG. 181.—Primary Battery of Chromic Acid Cells.

Zinc for six cells at 3s. 3d.	£0	19	6
Chromic crystals at 10d. per lb.	0	5	0
Acid solution at 2d. per cell	0	1	0
Total	£1	5	6

not to speak of labour or prime cost. The zinc, however, if carefully handled and reasonably pure, may serve another twenty hours; this would bring the cost per unit to about sixteen shillings for zinc and solutions only. The cost per hour would not be far from the above figure. The Daniells' cell, as modified by Lord Kelvin, in the shape of the tray battery, is another design for low internal resistance due to the large size of plates.

In this battery the hydrogen liberated at the negative plate is combined with sulphate of copper, forming copper and water. The hydrogen is thus disposed of in this cell, but it does not contribute any energy in the circuit, for the setting free of the copper absorbs about as much energy as the combination of the hydrogen develops. The electromotive force is therefore only about one volt, but so long as solution of copper sulphate is kept around the negative plate it is maintained coated with pure clean copper, and the electromotive force although small is constant.

The cell consists of a wooden tray lined with thin sheet lead (Fig. 182). In the bottom of this tray are placed a quantity of sulphate of copper crystals in an even layer, and above these, but some inches clear of them, is placed a cast zinc grid resting on wooden blocks. It is better to use stoneware trays on a large scale, with the thinnest sheet copper plates laid in the bottom.

The zinc grid is enveloped in parchment paper to help protect it from the copper sulphate. The idea of the cell is that the copper sulphate solution will remain at the bottom of the cell and the zinc sulphate solution float upon it.

A tolerably powerful and constant current can be obtained from a series of these cells (Fig. 183), at the expense of zinc and copper sulphate; the by-products are pure copper and zinc sulphate. These products can be sold to recover some of the outlay.

The Edison-Lalande cell is also a zinc copper cell, but requires a single fluid, a solution of caustic soda or potash. In single-fluid cells the hydrogen formed at the negative plate is disposed of by combining with a solid or gaseous substance connected with the negative plate. In the Lalande cell this substance is copper oxide, known as copper scale, and formed on copper sheet or wire when exposed to air at a red heat. When the copper cools it scales off, when a fresh coating can be formed by reheating.

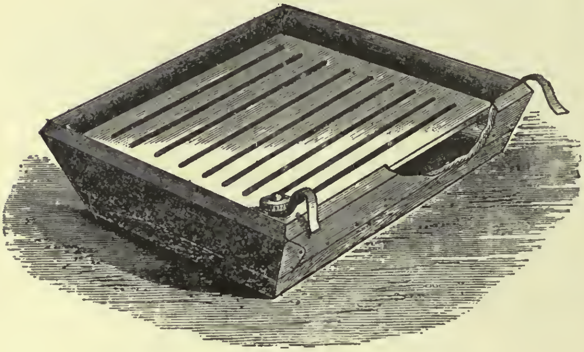


FIG. 182.—Tray Form of Primary Cell.

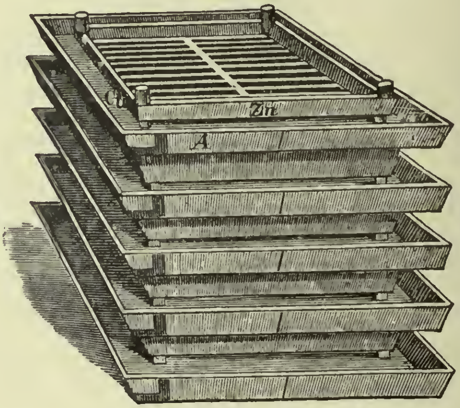


FIG. 183.—Battery of Tray Form of Primary Cells.

The copper oxide is formed into an agglomerate plate by making it up with clay or tar, and pressing it into solid form, then gradually heating to 700° C.

The cell is shown in Fig. 184, as supplied by the General Electric Company. The copper oxide plate is carried in a light copper frame, and can be easily replaced. A zinc plate is fixed on each side, and the whole carried on the lid. They are made up to 600 ampère-hours capacity, and 0.75 volts. A more energetic single-fluid cell is the Leclanche.

The General Electric Company also supply a large cell of this type, the "Carsack" cell, in which the substance employed to combine with the liberated hydrogen is manganese peroxide in contact with a carbon negative plate. The solution is ammonia chloride, commonly called sal ammoniac. The manganese peroxide is made up into an agglomerate around a carbon rod, and bound thereto by a piece of jute sacking and string. The zinc is a cylinder. It is shown in Fig. 185, and in Fig. 186 running a small fan motor.

The difficulty with these solid hydrogen absorbers is to keep them in good electrical contact with the negative rod or plate. They start off all right, but soon the solid oxide in nearest contact is reduced to a different compound and a bad conductor.

This manganese cell has not yet been fully investigated. There must be some better method of applying the peroxide than as an agglomerate or as a mixed powder with carbon. These solid substances should be used in thin layers spread over very large negative surfaces, which entails a large number of large plates.

On the whole question there does not seem to be a better battery for heavy work than the Daniells, in the large tray form, when properly attended to. This proper attention is often neglected with batteries, and this neglect is the cause of dissatisfaction in many cases. Theoretically, the cost of raw materials on a large scale, and allowing for copper recovered per Board of Trade unit of electricity, is for this cell about ninepence, to which must be added attendance, interest on cost, and allowance for depreciation and renewals.

The batteries described are the largest in ordinary use, but it must be pointed out that even they are far too small for any electrical prime mover except toys. If anyone wishes to run a prime mover from a primary battery he must be prepared for very large cells, plenty of plate surface, and abundance of solution. They can then be trusted to run for considerable time without much trouble, and give the steady current necessary for good working. The author many years ago, when the dynamo was an infant, designed a tray battery of Daniells' cells for electrotyping. The plates were 6 feet by 3 feet, or 18 square feet surface, and there were 12 cells. They were often run in two parallels, giving 36 square feet of plates. Large batteries of this class are usually arranged in series of piles, as shown in Fig. 183. In practice the costs are as follow:—

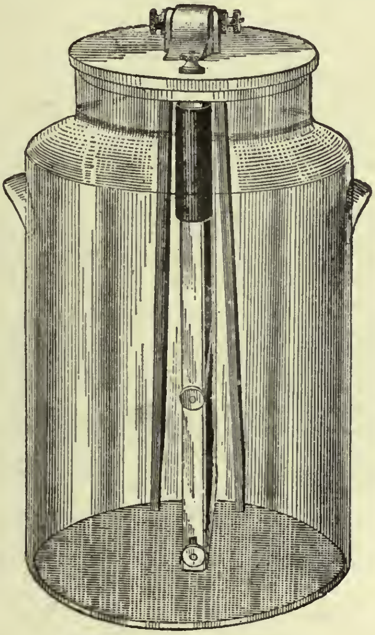


FIG. 184.—Edison-Lalande Primary Cell.

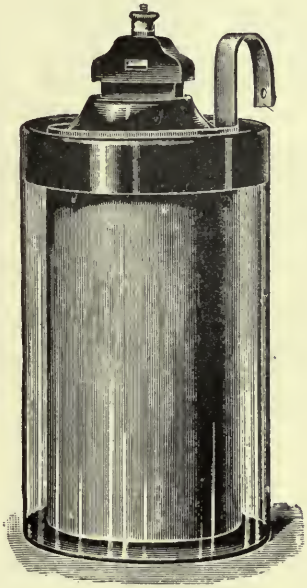


FIG. 185.—"Carsack" Leclanche Primary Cell.

The copper sulphate per Board of Trade unit required is about 11 lbs., at £22 per ton; the copper deposited for the same output is 2½ lbs., worth about £70 per ton. The zinc required per Board of Trade unit would be about 3 lbs., allowing for impurities, at say £18 per ton.

M. Reynier modified the Daniells' cell for heavy work. In his first cell (Fig. 187), the negative, was sheet copper, which had the shape represented in Fig. 188 placed in the vessel. Next comes a cell of parchment containing sheet zinc. Solution of copper sulphate is poured into the glass vessel, and sodium hydrate into the parchment cell. By substituting sodium hydrate for sulphuric acid, diffusion of the copper sulphate crystals is prevented, and also the electromotive force is increased from 1.3 to 1.5 volts. The dissolving of zinc when the battery is not in use is also prevented by means of this arrangement. He further modified the Daniells' element. The copper electrode took the form of a rectangular trough 22 centimetres high, 5 centimetres wide, and 40 centimetres long. The zinc plate, which is shorter by 10 to 12 centimetres than the copper electrode, is wrapped up in parchment. At the short end of each zinc a basket is placed to hold the crystals of copper sulphate. Tubes at the end of each element carry off the fluid. The elements are joined by means of short metal strips, which are held together by clamps. The copper sulphate solution (to which Reynier added calcium chlorate, sodium chloride, ammonia salts, etc., to diminish resistance) enters the parchment cell, where it is decomposed and thus furnishes the sulphuric acid for the zinc. The zinc sulphate diffuses through the walls of the cell and collects in the copper vessel. Every twenty-four hours 1 litre of fluid per element is replaced by water. These cells gave 1 horse-power in a battery of 68 cells, at a cost of two francs per hour.

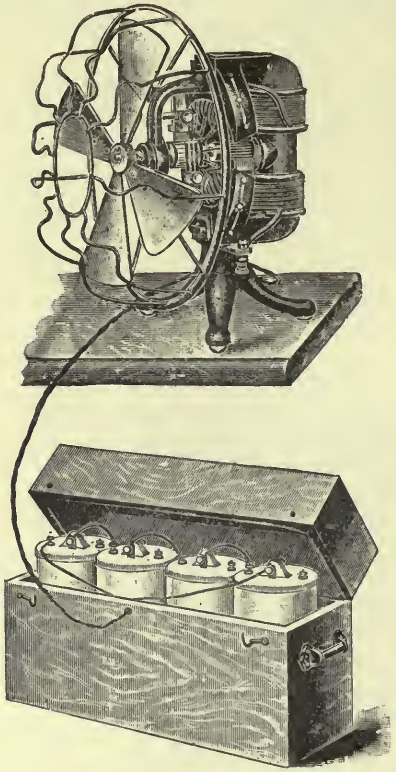


FIG. 186.—Primary Battery Driving Fan Motor.

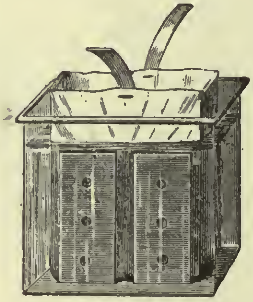


FIG. 187.—Reynier's Primary Cell.

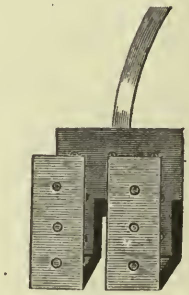


FIG. 188.—Copper Electrode of Reynier's Cell.

There is also the thermo pile, which converts about 2 per cent. of heat applied to it into electrical energy.

To engineers this part of the subject may not have much immediate interest. It is discussed here briefly, chiefly because it is to the direct production of electrical energy from fuel that the foremost electricians of the world look for the best solution of the problems connected with the generation of power.

The subject is one which few can pursue: it requires a considerable knowledge of electrolysis, chemistry, electricity, and dynamos in their most advanced stages, but it is a field of research promising the most valuable and important discoveries the world has ever revealed. The most hopeful line of research seems to lead to a gas battery consuming producer gas and atmospheric oxygen.

CHAPTER III

THE LOCOMOTIVE ENGINE

It is recorded that the earliest steam locomotive was proposed by Sir Isaac Newton. There was no engine to speak of about it: it had a boiler and furnace for raising steam. The steam was blown aft through a nozzle, and the reaction was expected to propel in a forward direction the carriage on which the boiler was carried.

One can scarcely believe that a man of Sir Isaac Newton's attainments made such a proposal; the reaction would at most only amount to the area of the nozzle multiplied by the pressure in the boiler. A very small nozzle discharges a large amount of steam at a very high velocity, and a little calculation would show that the carriage would have to run about ten miles a minute to get any efficiency out of the steam.

In 1829 George Stephenson first made a practical locomotive, the "Rocket" winning first place easily in a contest. It is shown in Fig. 189 as commonly represented.

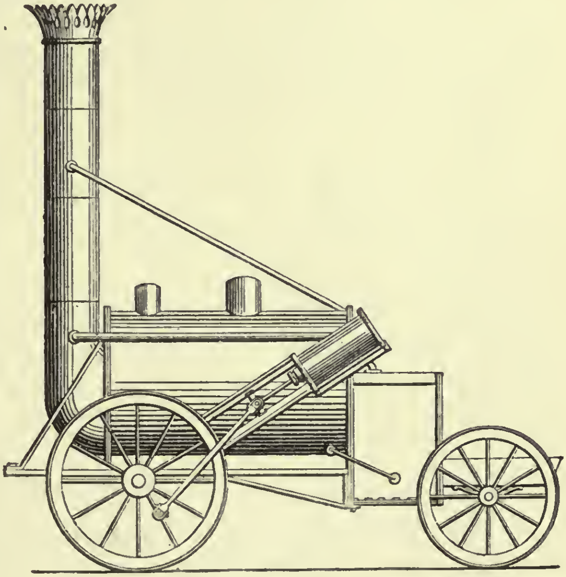


Fig. 189.—The First Stephenson Locomotive.

From this simple arrangement to the present-day locomotive, by short steps and many a long series of detail, improvements have been made.

The steam locomotive has reached its zenith, like other steam engines; and although, like all highly developed machines, it is not likely to be entirely superseded at any future date, as long as coal lasts, yet it must give way in many places to internal combustion locomotives, and secondary locomotives run by power transmitted by electricity.

The internal combustion locomotive has a good deal to recommend it from a theoretical point of view. The non-reversibility of the engine and difficulty of control at present prevents its extended use. Motor car people can put up with gear cases, clutches, and other cranky devices, but the locomotive and marine engineer will have none of them. These sort of things are all right for a time when they are new and well made, but their reliable life is short, and they soon become a source of danger and trouble. The useful life of a motor car is very short; a locomotive or marine engine must last long enough to pay for its cost. Locomotives propelled by steam engines fixed along the line and the power transmitted electrically have a great field of usefulness in crowded districts for short lines. But the advocacy of their application to long lines and heavy traffic cannot be the result of actual scientific knowledge and experience.

Electrically transmitted power of any magnitude soon becomes very costly, on account of the large capital expenditure required for long distance working. Considered only as locomotives, and shutting out the fact that they are dependent on power transmitted from a steam engine, the electric locomotive is a far superior machine to the steam locomotive, but it is this transmission of the power which is the crucial question. A great deal has been written about it by the rising generation of electrical engineers, but none of them have brought forward anything new or not known to early engineers of twenty years ago. We are still a long way from electrical railways of any importance, and the younger engineers have a great deal more to do than they have yet attempted before steam locomotives yield up the field to them for heavy work and long distance.

STEAM LOCOMOTIVE ENGINE

Stephenson afterwards elaborated the locomotive, adding the blast pipe to increase the draught, and the well-known link motion for controlling and reversing. It looks all very simple and straightforward work at this date; but if it is remembered that in Stephenson's time, and for long after, the commercial engine builders' fixed ideal of an engine was a heavy, bulky, spacious machine tied firmly to *terra firma* stone masonry by huge bolts, it will be admitted that it required courage and originality, together with mechanical genius, to conceive and put into practice an engine of small weight, high speed, and capable of running on a movable base, standing on four wheels, a foundation consisting of four points. The locomotive had to be constructed to be self-contained, the strains set up all resisted within its own rigid construction; and to be direct-acting within narrow space, and of much higher speeds than was then common. All these features are admirably exhibited in the "Rocket."

Modern locomotive engines have been pretty well reduced to common designs, so that a few examples of leading firms' products will suffice for our purpose.

THE VALVE MOTION

The valve gearing commonly used is the Stephenson, shown in plan and elevation in Fig. 190.

Referring to the elevation, V is the slide valve, S the valve spindle working through a guide sleeve K. L is the link which can be moved up or down by the rod R, which connects to the controlling lever on the foot plate. The motion is transmitted by levers B, E, A, and the weights balanced by a counterweight W. The forward and backward eccentrics H and their rods F, B are connected to opposite end of the link L.

Dimensions of Valve Motion

	Ft.	Ins.
Length of expansion link between centres	1	$4\frac{1}{2}$
,, eccentric rods	4	8
,, lifting links	1	$10\frac{5}{8}$
Diameter of motion pins	0	$1\frac{3}{4}$
,, eccentric sheaves	1	$4\frac{1}{4}$
Throw of eccentric sheaves	0	$3\frac{1}{4}$

The rod R is operated by a screw and hand-wheel, which locks the motion in any desired position.

All the valves are gun-metal. The motion pins and all parts subject to friction are made of finest iron and the surface case hardened.

Locomotives are made with inside cylinders and outside cylinders. In the first case the cylinders are inside the frame, and the connecting rods couple on to a 2-cranked main driving shaft, have the two sets of eccentrics for the valve motion between, keyed on in two halves.

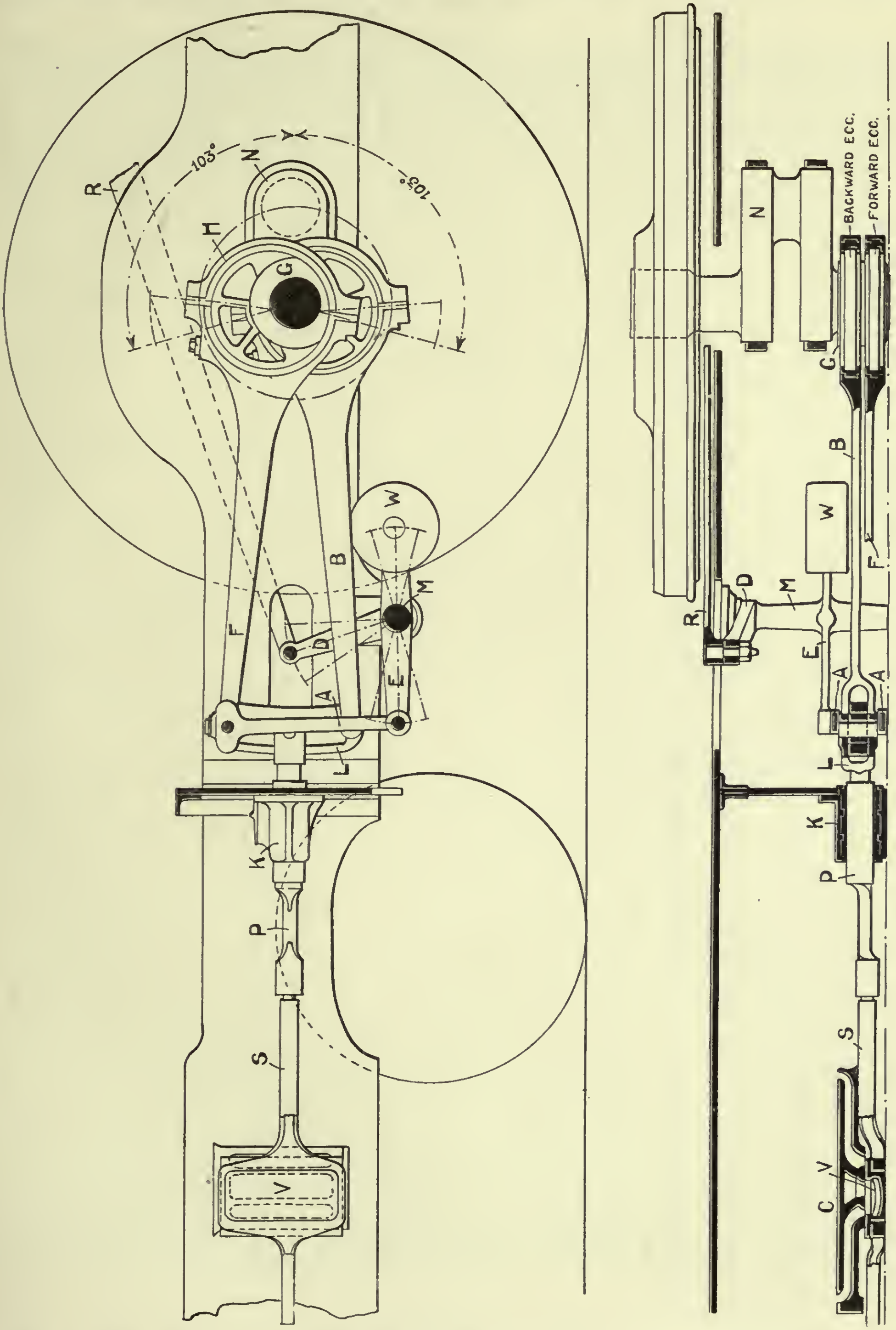

R
103°
N
Y
H
G
103°
W
B
M
F
D
E
A
L
K
P
S
V
N
BACKWARD ECC.
FORWARD ECC.
C
B
W
F
D
M
R
E
A
A
L
K
P
S
C
V

FIG. 190.—Stephenson's Valve Gearing for Locomotive.

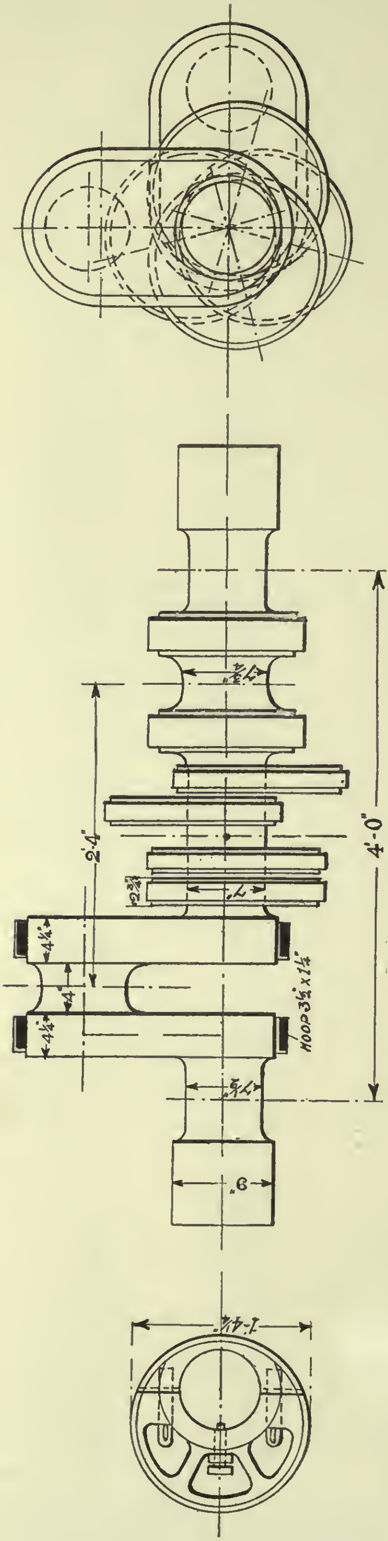


Fig. 191.—Locomotive Crank Axle.

The crank shaft shown in Fig. 191 is one made for inside cylinders; the main driving wheels being keyed on each end. The cranks are hooped by bands of best steel or iron, in order to strengthen the web of the cranks.

Usually the cylinders and their valve casings are bolted on to the saddle which carries the boiler, but in some cases they are cast all in one piece with the saddle; an example of this practice is shown in Fig. 192, by the American Locomotive Company. It enables the valve centres to come nearer the centre line of the locomotive, thus allowing of a better design of valve motion.

This cylinder is provided with a piston valve, and is of improved design. It will be seen from the illustrations (Figs. 192 and 193) that a portion of the valve chamber and cylinder have been removed in order to show more clearly the construction of the valve, the bushes, and bypass valves, and their relation to the steam passages in the casting. Fig. 192 also shows that the barrel is lined, and that the steam chest is provided with a bush. The valve is of the internal-admission type, and exhausts at the ends. It will also be seen by reference to Fig. 193 that the steam-inlet passage A is separated from the exhaust passage B, and from the body of the casting, by an air space, incoming steam therefore not being cooled by contact with the walls of the latter. There are outside cylinder engines in which the crank shaft is plain and the crank pin carried on the driving wheels.

In both types of locomotives the driving wheels are coupled by rods to other pairs of wheels, forming two couples, three couples, four couples, and so on.

Again, locomotives are divided into tank locomotives and tender locomotives. In the first class the water and coal supplies are carried on the locomotive, and add to the weight on the wheels; in the second class these supplies are carried on a separate vehicle called a tender.

The engines are mostly simple high-pressure engines, but some compound engines are also used. Whether the saving affected by compounding compensates for the complication of additional parts is a moot question.

A locomotive working at full load hauls a ton-mile at such a low figure of coal consumption, even with simple engines, that a saving in coal cannot amount to much, whereas a compound locomotive costs a good deal more at first, and may require more expenditure in maintenance.

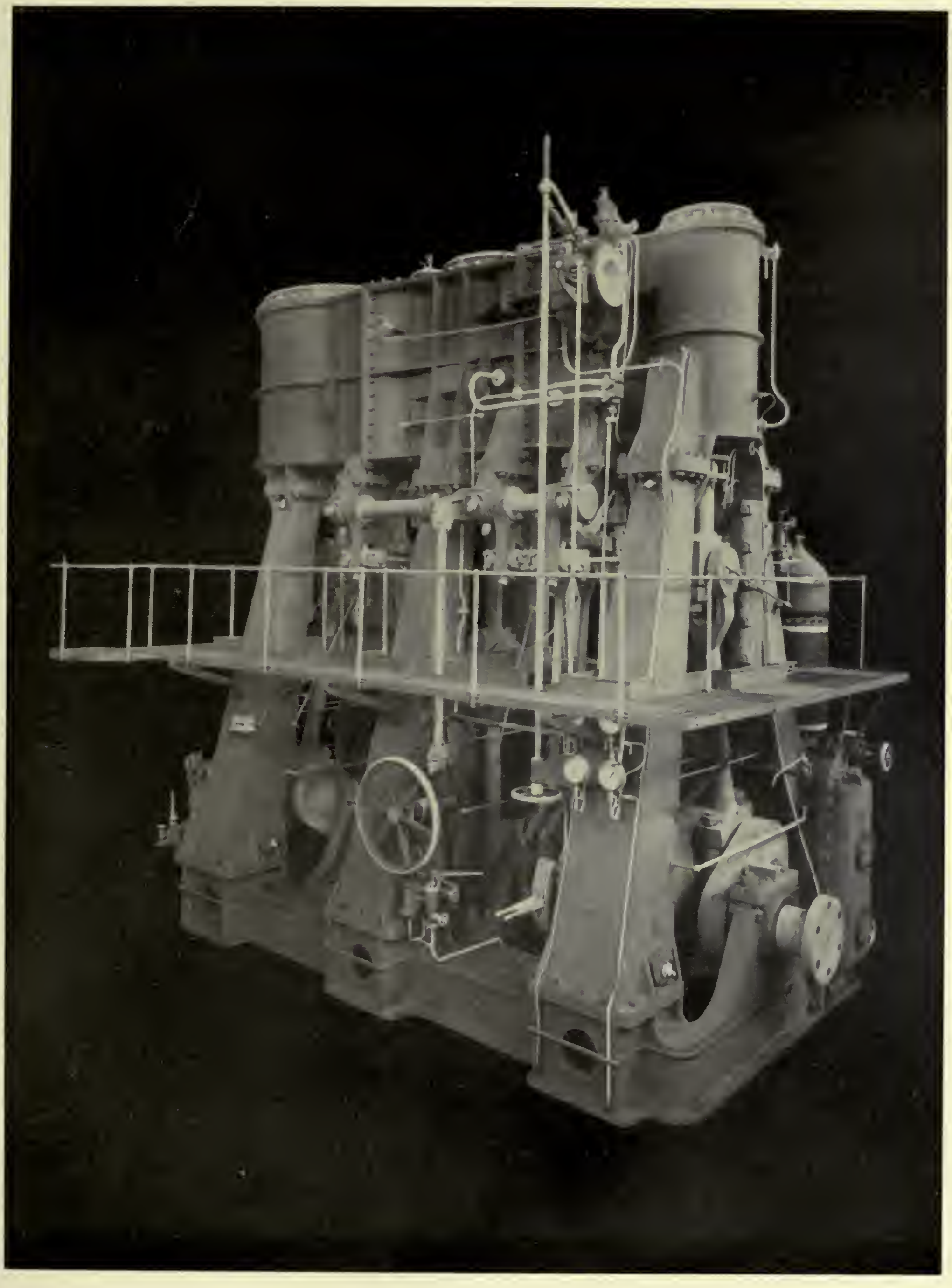


Plate VI.—Front View of Triple-Expansion Three-Cylinder Marine Engine.

At small loads it would not be as economical as the simple engines. Those who use them, however, claim that they justify their existence and effect a considerable economy.

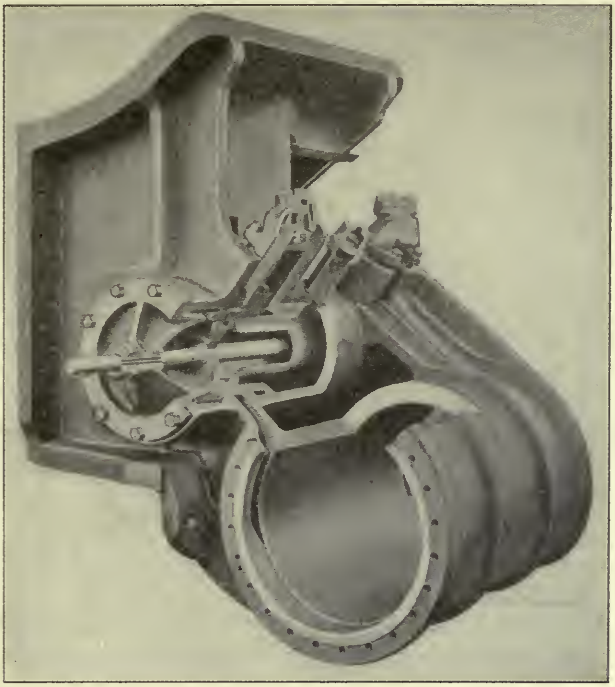


FIG. 192.—Locomotive Cylinder and Valve.

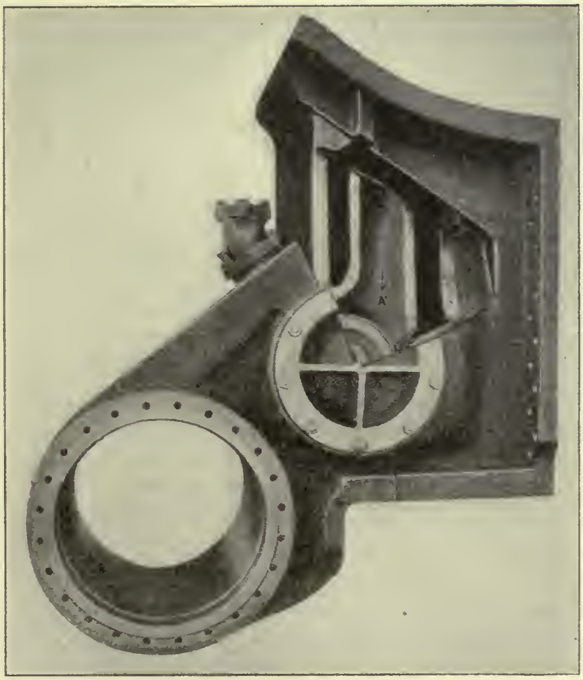


FIG. 193.—Locomotive Cylinder and Valve.

The gearing shown in Fig. 190 is that for an inside cylinder engine with cranked shaft. An example of this class is shown in Fig. 194, with a saddle tank and three pair of coupled wheels; these are coupled to cranks outside the main bearings. The coal is carried in a coal box behind the driver's cab.

Diameter of cylinders	17½ inches.
Stroke	2 feet.
Coupled wheels	4 feet 7 inches diameter.
Trailers	3 feet 8 inches.
Wheel base	15 feet 3 inches driving.
Total wheel base	21 feet.
Boiler	11 by 4 feet.
Railway gauge	4 feet 8½ inches.
Fuel space	140 cubic feet.
Water capacity tank	12,000 lbs.
Weight empty	45 tons.
,, loaded	57 tons.

Built by Messrs. Hudswell, Clarke, & Co., Railway Foundry, Leeds, for Rhymney Railway, South Wales.

The same firm show the locomotive (Fig. 195) with outside cylinders for narrow gauge of 3 feet, 3 pair coupled wheels with a bogie in front; the engine is carried on 8 wheels, 6 drivers and 2 trailers, and a 4-wheeled bogie; the rigid base is only 9 feet.

Diameter of cylinders	1 foot 6 inches.
Stroke	1 ,, 10 ,,
Diameter of coupled wheels	3 feet 9 ,,
,, trailers	2 ,, 6 ,,
,, bogie	2 ,, 6 ,,
Boiler	10 feet by 3 feet 9 inches.
Fuel space	56 cubic feet.
Tank capacity	8500 lbs.
Empty weight	33 tons 6 cwts.
Weight loaded	41 tons.

The tanks are at the side.

The three figures (Figs. 196, 197, and 198) show a plan and end and side elevation, all partly in section.

The side elevation shows, without going into all the smaller details, the general design. At A is shown one of the slide valve cylinder faces with the centre line of the valve and piston rod *b*, *c*, showing the valve-connecting rod D bent to clear the axle E, and working into the link F. The rest of the gear is not shown, namely, the connecting rods, valve rod, eccentric rod, etc., as these are already shown in Fig. 195. The steam for the engine is taken from the dome G, through a slide valve on the mouth, H, of steam pipe K; this valve is operated by the lever L by the driver, and regulates the steam supply to the engine. The exhaust steam escapes through the blast pipe M, and creates a partial vacuum in the smoke box N, thereby drawing plenty of air through the fire grate, and flame through the boiler tubes.

The link motion is operated by the hand wheel O, which has a screwed spindle on which a nut P, connected to the motion rod R, is threaded. By means of this handwheel the engine can be reversed and the cut-off of the steam in the cylinders adjusted as required. SS are the draw-bar springs, volutes of sheet steel.

The bogie is swivelled on a pivot T, rigidly attached to the castings Q. The safety valves are shown at W, a pair of spring loaded valves.

Referring to the plan, the cylinder A_1 is in centre line with the main driving crank pin *b*, which is connected to cranks *c* and *d* by the side rods not shown. The eccentrics are keyed on at *c*. *ff* is the steel plate side frame carrying the main bearings.

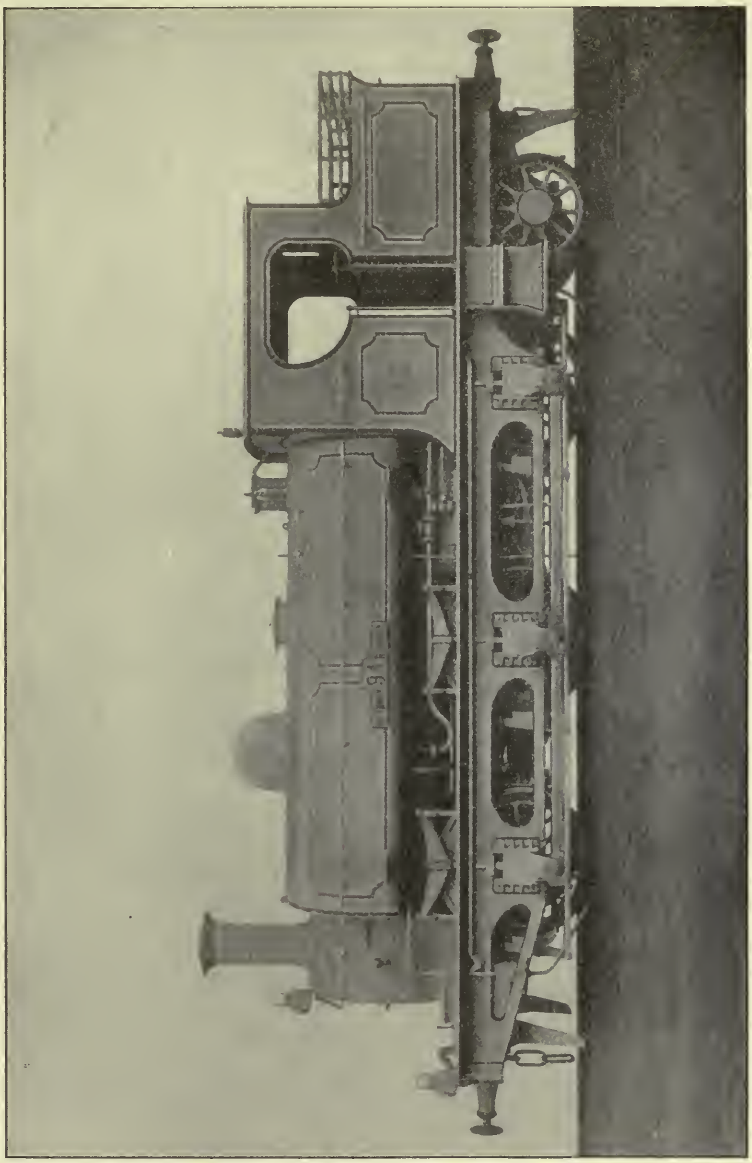


Fig. 194.—Saddle Tank Locomotive.

In the end sections the cylinder A_1 is seen, also its valve chest A; also the pivoting of the bogie at T on a rigid steel casting Q, and one of the main driving cranks *b*, the steam pipe K, and the exhaust M.

The foregoing description outlines the main features of the engine without reference to the boilers. The boilers will be treated with other boilers in Volume VI.

A tank locomotive by Messrs. Robert Stephenson, Newcastle, is shown in Plate VII. complete, and in Fig. 200 a side elevation, in Fig. 199 an end elevation, and Fig. 201 a plan, partly in section, and showing every detail. It is a powerful tank engine for narrow gauge, 3 feet. It is designed to take a 2-chain curve, having a bogie at the fire-box end instead of at the smoke-box end, as in the last example. It was designed to take a load of 132 tons up an incline of 1 in 30 at 12 miles an hour. An essential requirement was that the wheel base should lie as short as possible on the rigid base. This comes out at 7 feet 5 inches in the design, with a total wheel base of 18 feet 3 inches.

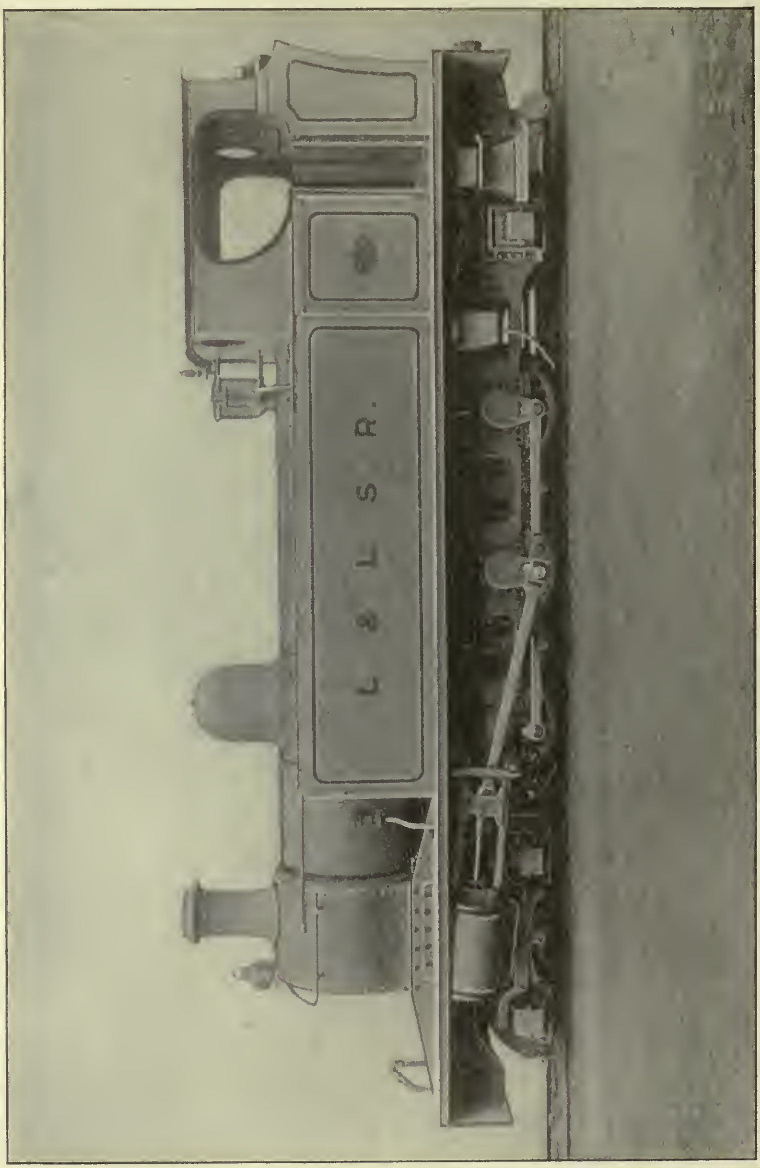


FIG. 195.—Side Tank Locomotive.

In order to obtain these, the coupled wheels have been kept as close together as possible, and are all in front of the fire box. Immediately behind the driving wheels is a steel casting, arranged to admit of the frame at back end of engine being widened out to allow the use of a wide fire box. The necessary grate area is then obtained in width rather than in height of fire box, and the engine is kept as short as possible.

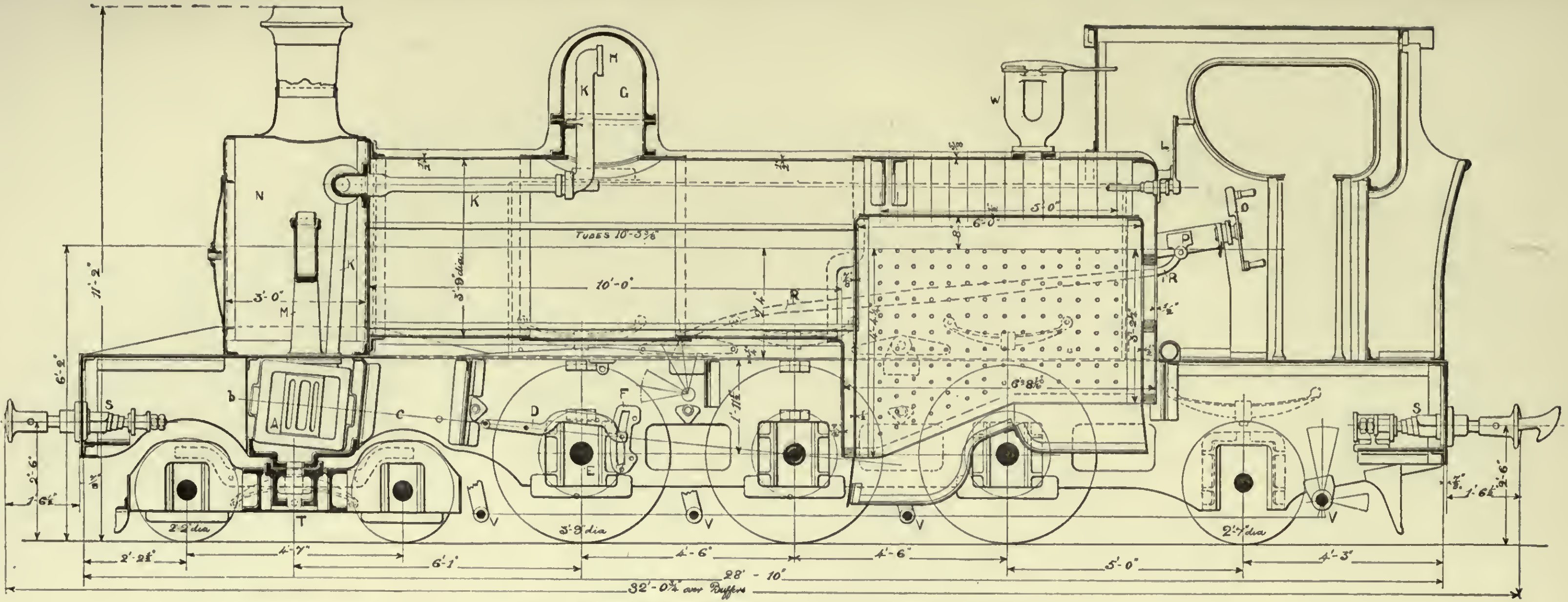

N
K
G
H
M
3'-0"
TUBES 10'-3⅜"
10'-0"
3'-9" dia
6'-0"
5'-0"
6'-8½"
W
L
O
P
R
A
b
C
D
F
E
T
S
V
2'-2" dia
3'-9" dia
2'-7" dia
11'-2"
6'-2"
2'-6"
1'-6½"
2'-2½"
4'-7"
6'-1"
4'-6"
4'-6"
5'-0"
4'-3"
28' - 10"
32'-0½" over Buffers

FIG. 196.—Sectional Elevation of Side Tank Locomotive.

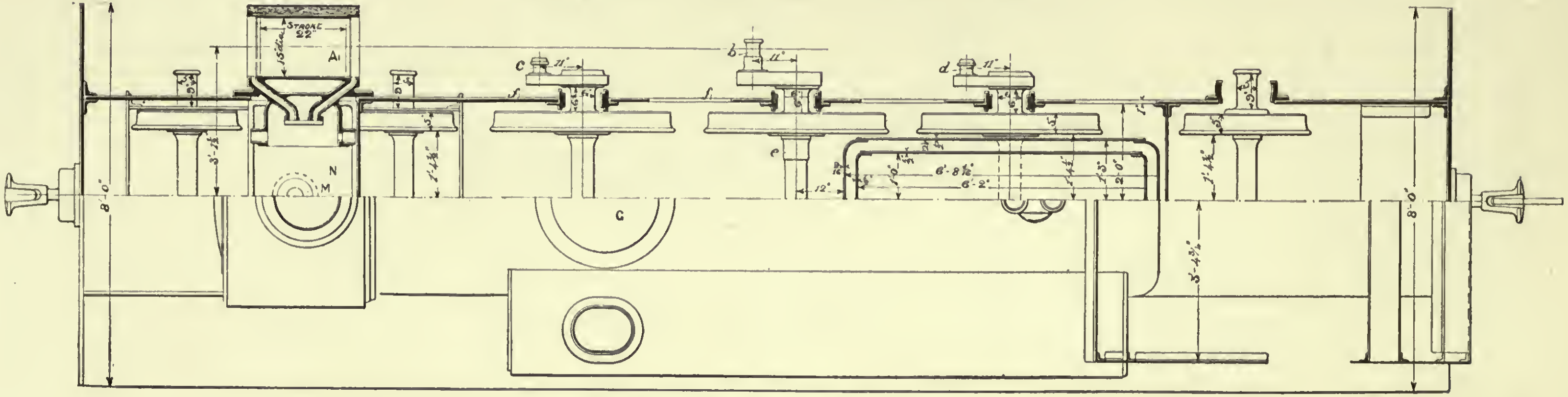

STROKE 22"
15" dia
A1
N
M
G
b
c
d
e
f
11"
3'-1½"
1'-4½"
6'-8½"
6'-2"
12"
2'-0"
8'-0"
3'-4½"

FIG. 197.—Sectional Plan of Side Tank Locomotive.

The principal dimensions are as follow :—

Cylinders	15 inches displacement by 20 inches stroke.
Diameter of coupled wheels	3 feet 3 inches.
Diameter of bogie wheels	2 ,, 1 ,,
Fixed wheel base	7 ,, 5 ,,
Total wheel base	18 ,, 3 ,,
Heating surface in tubes	680.75 square feet.
,, ,, fire box	65.75 ,,
Total	746.5 ,,
Grate area	14 square feet.
Working pressure	150 lbs. per square inch.
Capacity of tanks	700 gallons.
,, bunker	66 cubic feet.
Tractive power, cutting off at 75 per cent. of stroke	15,500 lbs.

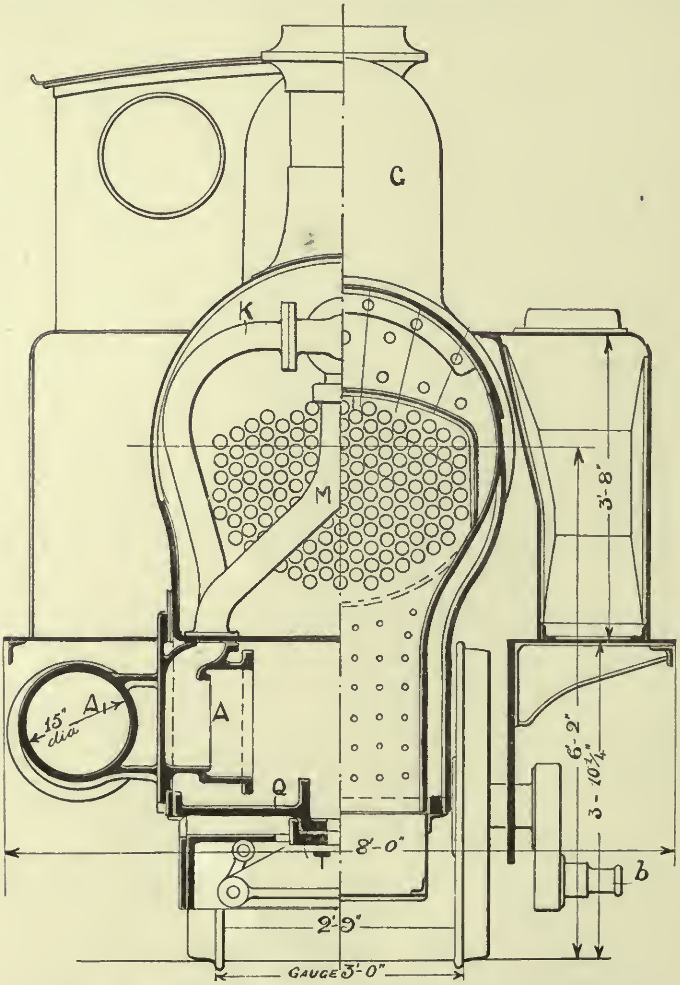


FIG. 198.—Sectional End Views of Side Tank Locomotive.

The engine is fitted with vacuum and hand brake, and all the latest features in locomotive practice are embodied in the design.

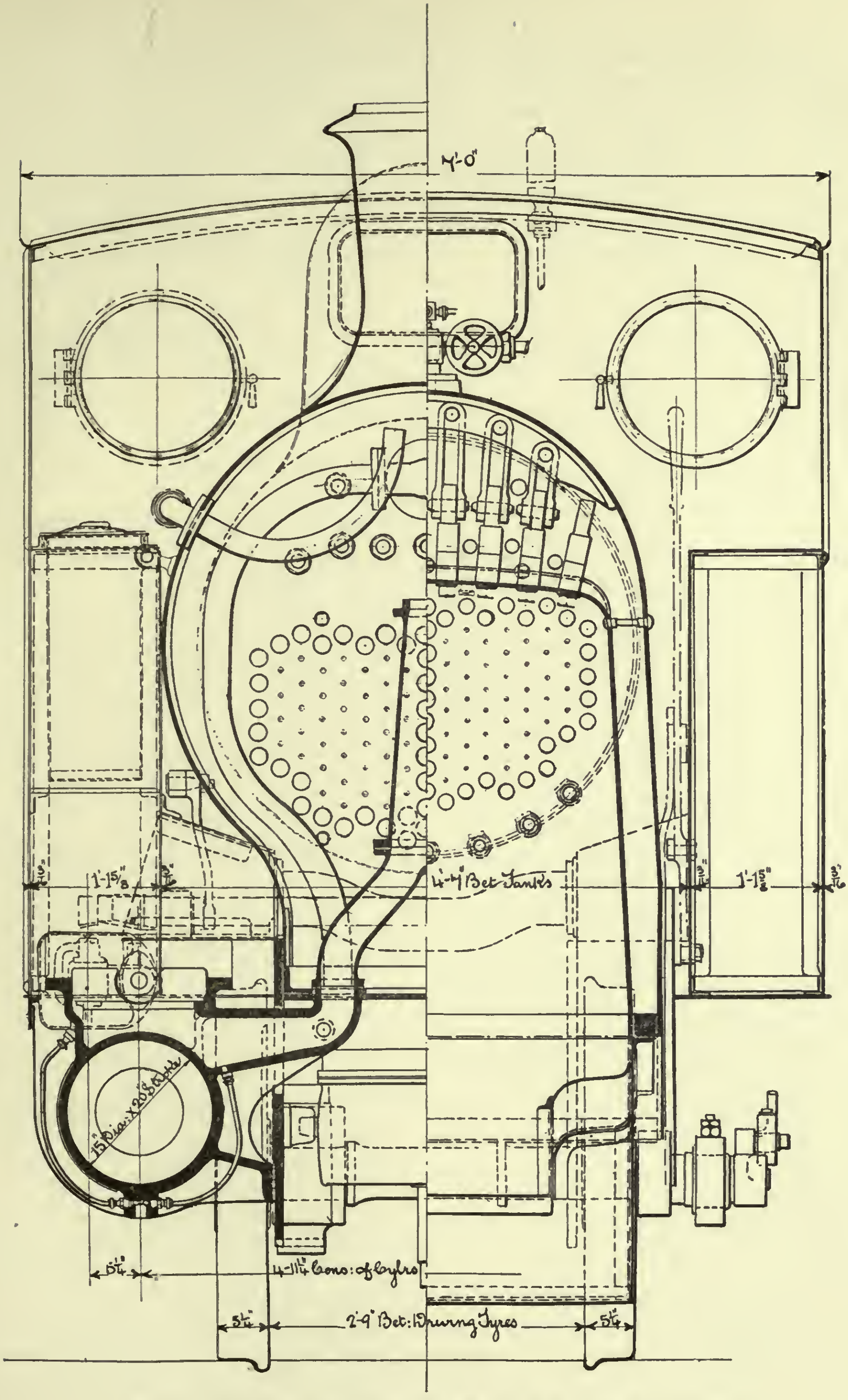

7'-0"
3/4"
1'-1 5/8"
3/4"
4'-4" Bet: Tanks
3/4"
1'-1 5/8"
3/16"
15" Dia: X 20" Stroke
5 1/4"
4'-11 1/4" Cens: of Cylrs
5 1/4"
2'-9" Bet: Driving Tyres
5 1/4"

FIG. 199.—Sectional End Views of Powerful Side Tank Locomotive.

The slide valves in this engine are on the upper side of the cylinders and operated by an outside crank gear from the main crank pin and a link motion, working on the principle of the single eccentric valve gear.

In narrow gauge locomotives there is small space between the frames and beneath for gearing, hence many locomotives are now made with all the gearing outside of the frames, with this form of valve gearing.

This style of valve gearing is much used in Germany; it is known as Waalschaert's gearing, and is more particularly shown in detail in Fig. 202, a part plan and elevation. A crank on the main crank pin works the link, and a lever driven from the cross-head compounds the motion, so that the cut-off is varied and the valve set in the backward or forward position.

In Robert Stephenson & Co.'s engine the travel of the valve is 4 inches forward and $3\frac{7}{8}$ inches backward. Throw of eccentric, $6\frac{3}{4}$ inches; radius of link, 2 feet $2\frac{3}{8}$ inches; lap of valve, 1 inch.

It has two brakes, a hand brake in which the screw and levers give a brake power equal to $P = \frac{32 \times 50.26 \times 9 \times 8 \times 20.5}{0.5 \times 5 \times 3.5 \times 12 \times 2240} = 10.9$ tons, and a vacuum brake which gives a power equal to $P = \frac{346.36 \times 18 \times 20.5}{12 \times 4 \times 2240} = 1.18$ tons per lb. of pressure in brake cylinder. The brake rods and vacuum cylinder are shown in the plan.

The regulator slide valve is shown in section in the dome, and is operated by the lever shown on the boiler front.

The three figures (Figs. 199, 200, and 201) are complete and to scale, and dimensioned so that every detail can be observed wthout further description.

Messrs. Stephenson's large main line locomotive is shown in Fig. 203 complete, and in section in Figs. 204, 205, and 206. It has outside cylinders and ordinary valve motion by link.

Lap of valve	1″
Angle of forward eccentric	102°
,, backward eccentric	$102\frac{1}{2}$°
Travel of valve, forward gear	$4\frac{9}{16}$″*b*
,, backward gear	$4\frac{1}{2}$″*b*

The bogie has only two wheels, and is under the smoke-box end.

The following is a summary of the principal dimensions:—

Cylinders	21 by 26-inch stroke.
Diameter of coupled wheels	4 feet 8 inches.
,, radial wheels	3 ,, 6 ,,
Fixed wheel base	16 ,, 0 ,,
Total	24 ,, 2 ,,
Heating surface in tubes	2062 square feet.
,, ,, fire box	173 ,,
Total	2235 ,,
Grate area	32 square feet.
Working pressure	180 lbs. per square inch.

The total weight of the engine in working order is 67 tons 2 cwts.

The tender carries 3500 gallons of water and 6 tons of fuel, weighing in working order 40 tons 6 cwts. The tractive force, taking 90 per cent. of boiler pressure, is

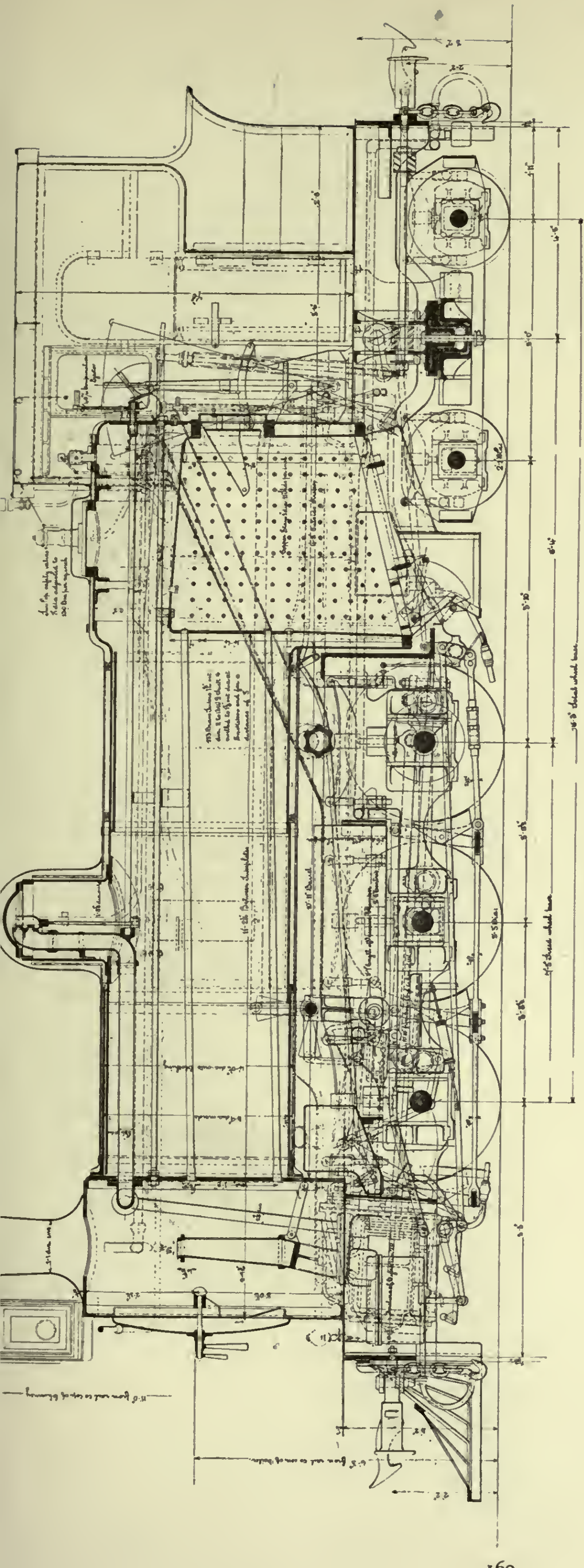


Fig. 200.—Sectional Elevation of Powerful Side Tank Locomotive.

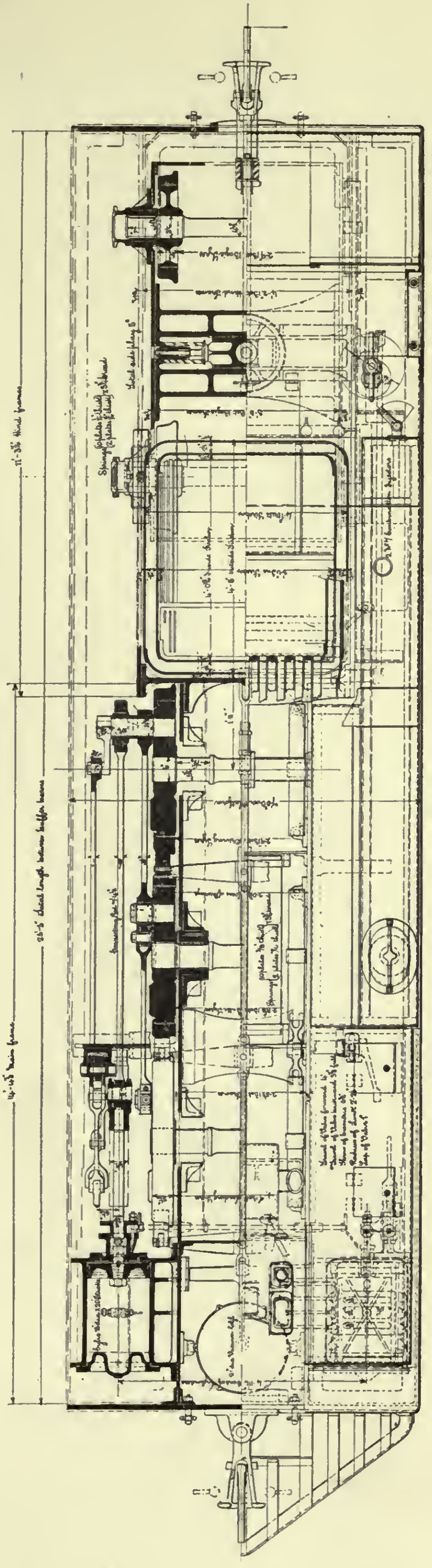


Fig. 201.—Sectional Plan of Powerful Side Tank Locomotive.

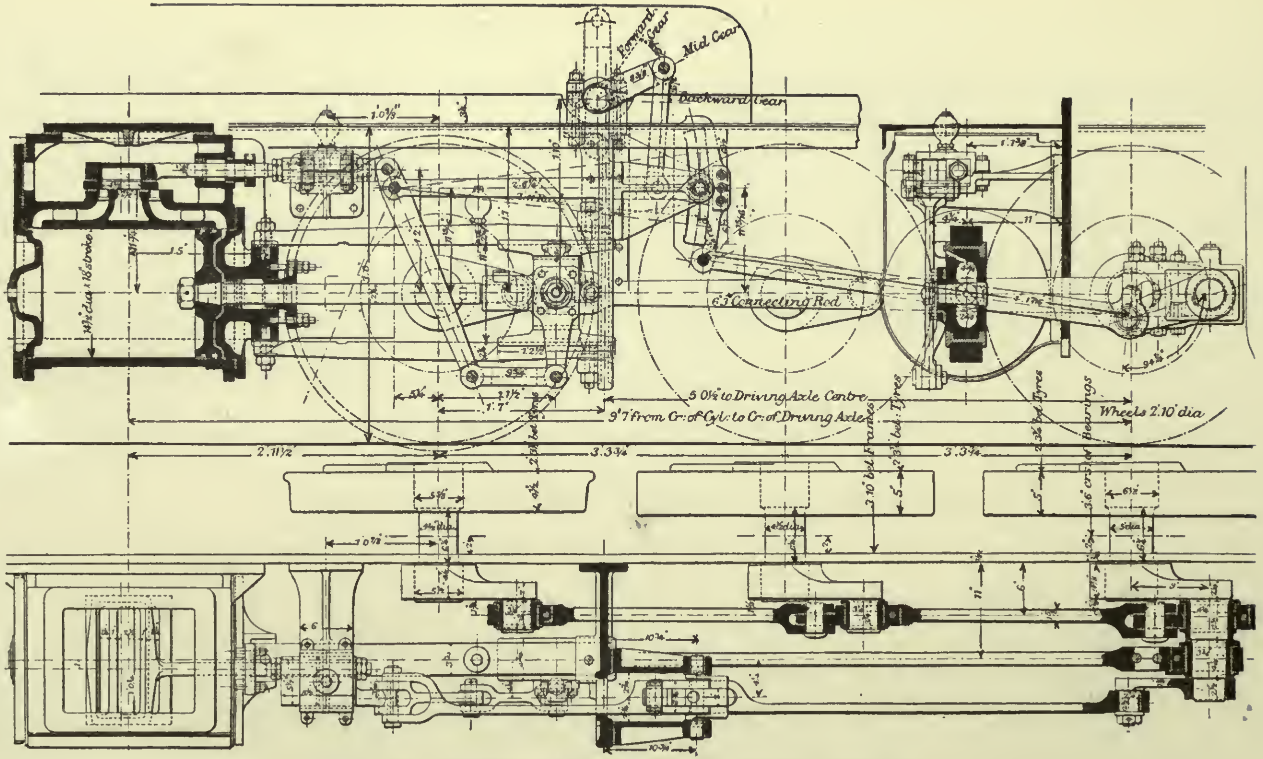
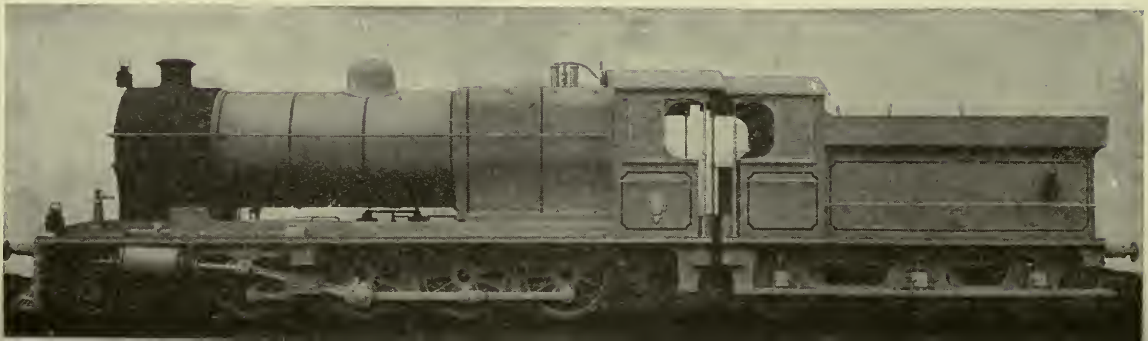

Forward Gear
Mid Gear
Backward Gear
1.0⅜"
14½ dia × 18 stroke
6.3 Connecting Rod
5.0½ to Driving Axle Centre
9.7 from Cr. of Cyl. to Cr. of Driving Axle
Wheels 2.10 dia
2.11½
3.3¾
3.3¾
3.10 bet. Frames
2.3¾ bet. Tyres
3.6 crs. of Bearings

FIG. 202.—Details of Waalschaert's Locomotive Valve Gear.



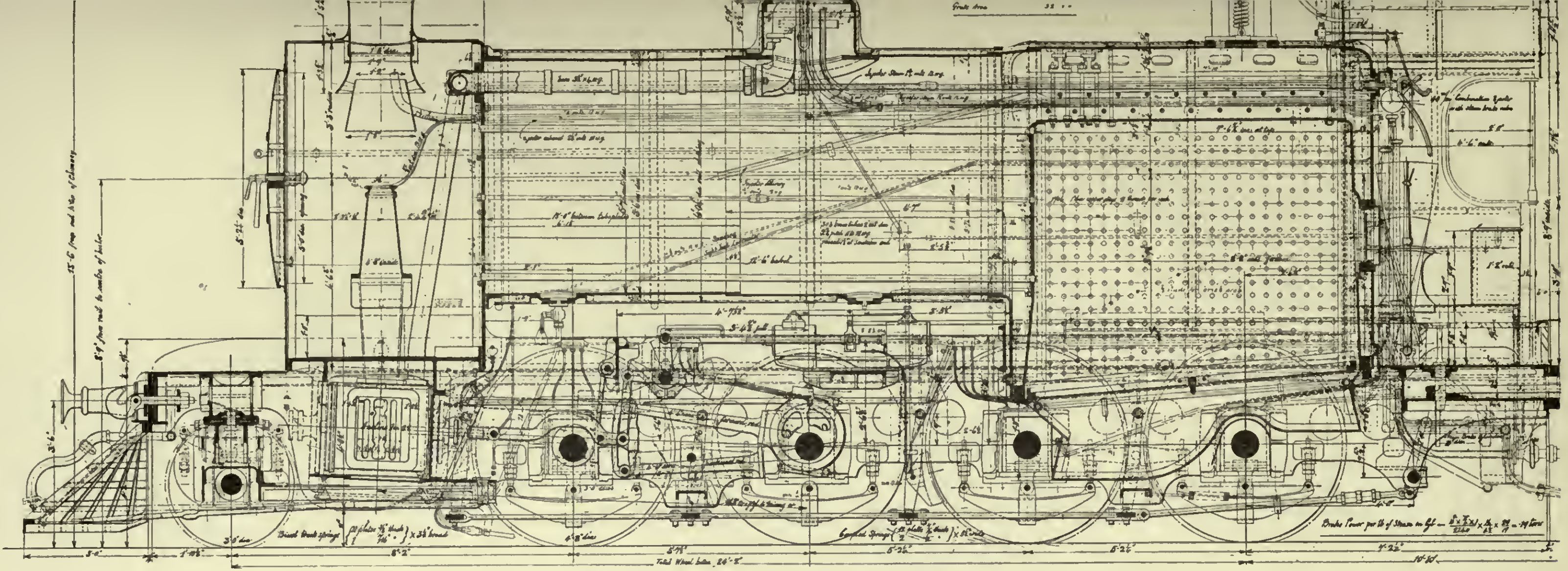

Brake Power per lb of Steam on Eqt
Total Wheel base 24'-5"
3'-6" dia
4'-8" dia
5'-7½"
5'-2½"
5'-2½"
4'-2½"
6'-2"
3'-0"
10'-10"

FIG. 204.—Sectional Elevation of Large Main Line Locomotive.

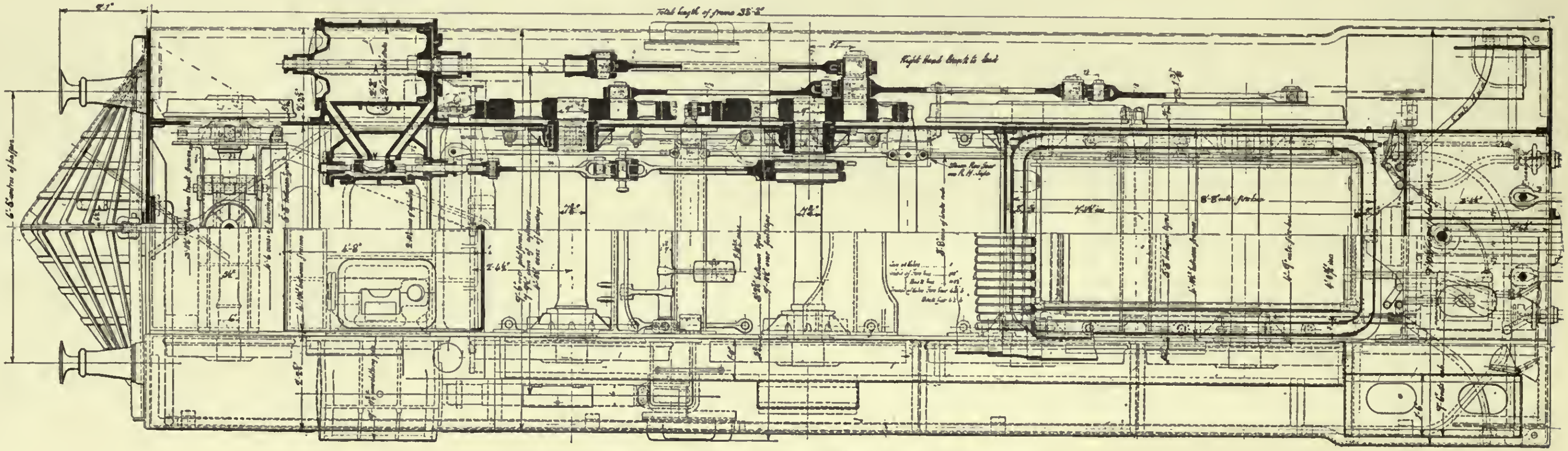

Total length of frame 35'-8"
Right Hand Coupled to Lead
6'-8" centres of buffers

FIG. 205.—Sectional Plan of Large Main Line Locomotive.

33,169 lbs. All further particulars may be obtained from the general arrangement drawing. These engines take with ease 1800 tons up a grade of 1 in 200.

Fifty-seven engines of this type have been built. This engine represents the most powerful, having eight coupled wheels, which can be built for 5 feet 6 inch gauge without exceeding a maximum axle load at the rail of 15.25 tons.

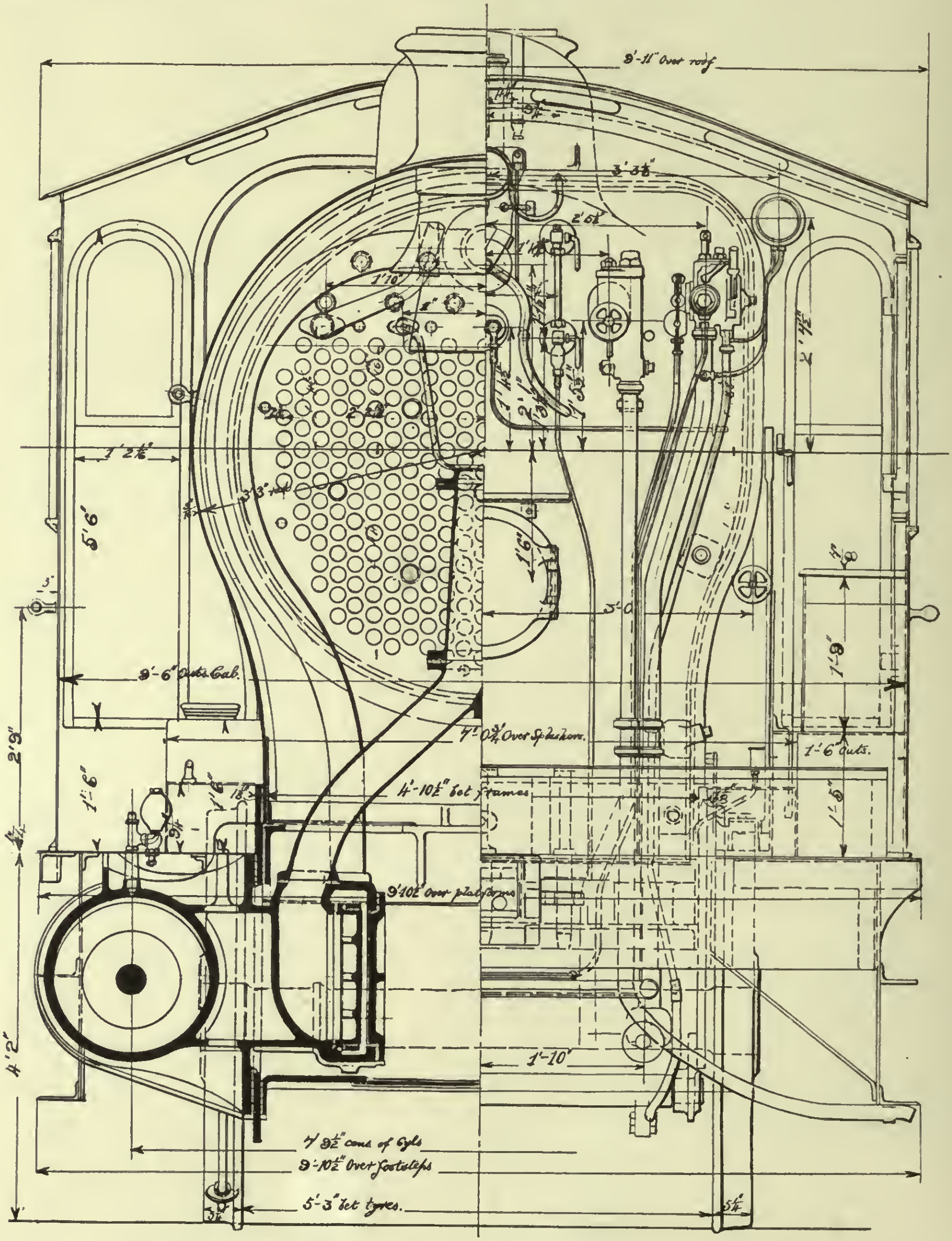

9'-11" Over roof
3'-3½"
2'-6½"
1'-10"
1'-1½"
2'-2½"
3'3" rad
1'-2½"
5'-6"
3"
2'-4½"
1'-6"
5'-0
2'-4½"
1'-9"
9'-6" Outs. Cab.
7'-0¾" Over Splashers.
1'-6" Outs.
2'-9"
1'-6"
4'-10½" bet frames
1'-5"
9'-10½" Over platforms
4'-2"
1'-10"
7'-9½" cens of Cyls
9'-10½" Over footsteps
5'-3" bet tyres.
3½
5¼

FIG. 206.—Sectional End Views of Large Main Line Locomotive.

A continental engine by the Hanover Engine Construction Company is shown in detail in the following figures (Figs. 207 to 212). Both the high-pressure and the low-pressure cylinders drive the same axle, the former on the inside, the latter on the outside (Fig. 210). The high-pressure and low-pressure cylinders on each side form one casting with their valve chests, and the two pairs of cylinders are bolted together along the middle line of the engine. A combination frame of bars and sheets has been adopted to suit this construction.

The chief novelty, the valve gear, was designed and patented by the well-known expert on railway engineering, Mr. von Borries, of Hanover, especially for use on 4-cylinder compound locomotives. The construction is simple and inexpensive. The pistons of the high-pressure and low-pressure cylinders act upon an inside and an outside crank, set so that the two pistons move in opposite directions, and the masses are to a certain extent balanced as to horizontal movements. The link gearing is common to the two pistons of a pair of cylinders.

In the arrangement, shown in Figs. 210 and 211, piston valves, with admission on the inside, are employed for the high-pressure cylinders, and flat slide valves for the low-pressure cylinders. The slide valves of the two cylinders do not describe equal paths, being actuated from different points, *c d* (Fig. 212), of the main lever, *a b*, of a Hensinger valve gear; *d*, belonging to the low-pressure slide valve, is nearer to the pin *a* than *c*. The high-pressure cylinder valve will therefore always be in advance of the low-pressure valve, and the former will work with a shorter cut-off.

In practice it is preferable to add an intermediate shaft to the link gear. A special lever for each slide is attached to the forked ends of this shaft, and the lower arm of this lever is connected with the cross-head of the respective piston. The ratio of the strokes will depend upon the relative lengths of these levers, whilst the influence of the length of the connecting rod upon the steam distribution will almost be eliminated. It will be seen that in these constructions two of the ordinary 4-valve gear devices are dispensed with.

Fig. 213, by Messrs. Dick, Kerr, & Co., illustrates a type of locomotive extensively used on sugar plantations, contractor's work, pit banks, and for conveying passengers and goods over light railways. The standard diameter of the cylinders are 6, 7, or 8 inches, and the gauge of the line 18 up 42 inches. The valve motion is "Morton's Patent," and, being arranged outside the frames, can be conveniently got at for repairs or renewals.

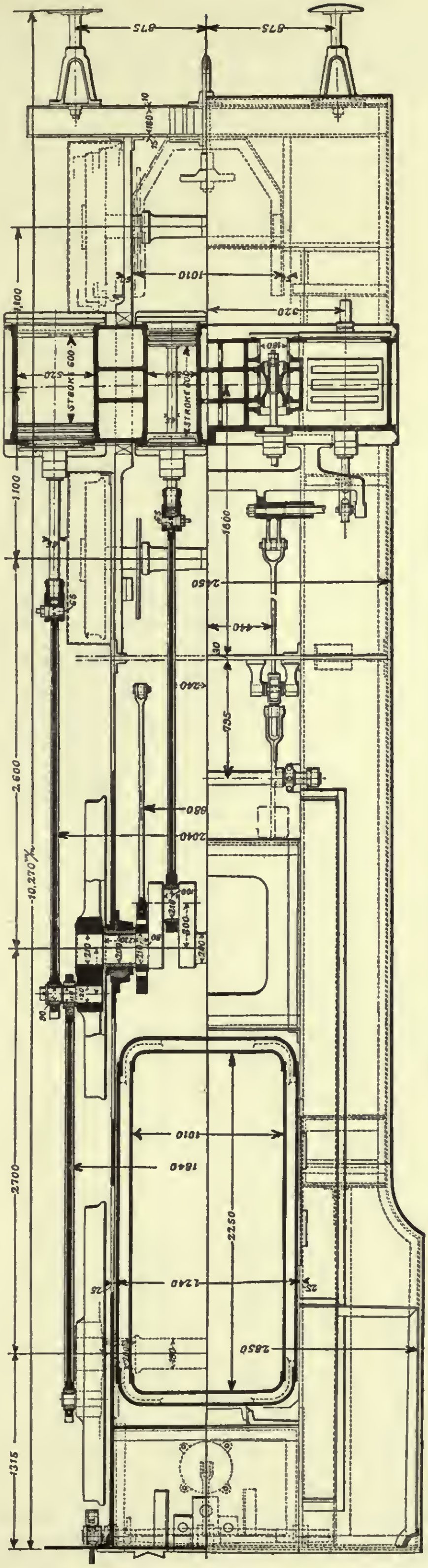


Fig. 207.—Sectional Plan of 4-Cylinder Express Locomotive.

The water tank is of the side-and-under type, which keeps the centre of gravity low, and this makes the running of the locomotive very steady. Coal bunkers are arranged at the sides. The buffers are of the central type, which are the most suitable for narrow-gauge rolling stock. The locomotive, with 7-inch cylinders, is mounted on four 24-inch diameter coupled wheels. Wheel base, 4 feet. The boiler is 2 feet 3 inches diameter, and is provided with copper fire box 2 feet 4 inches long, 1 foot 9½ inches wide, and 2 feet

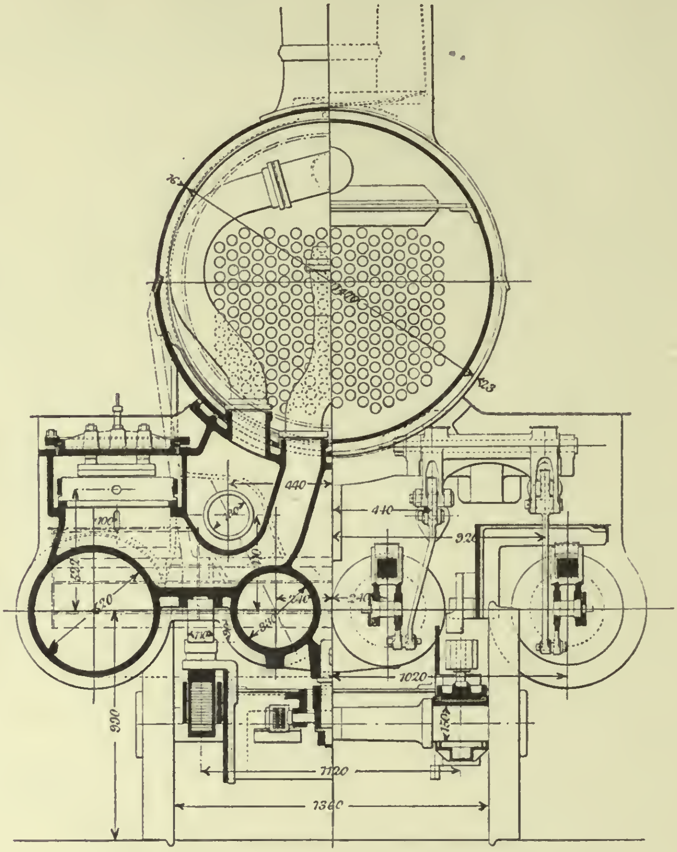

76
1400
123
440
410
926
100
240
240
840
1020
150
990
1120
1360

FIG. 208.—Sectional End Views of 4-Cylinder Locomotive.

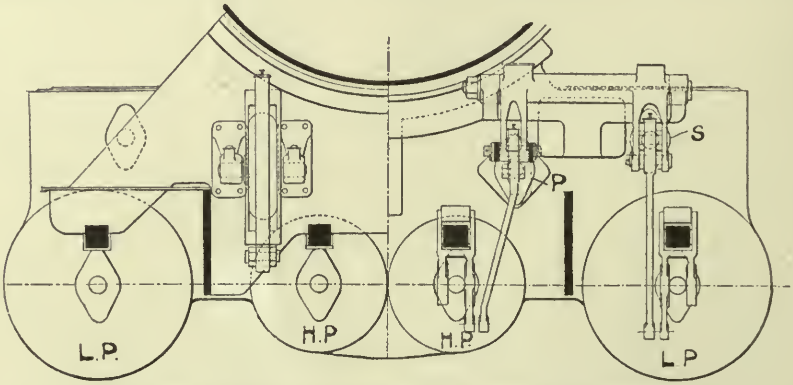

S
P
L.P.
H.P
H.P
L.P

FIG. 209.—End View of Cylinders of Express Locomotive.

6 inches deep, giving a heating surface of 21 square feet. There are forty $1\frac{3}{4}$-diameter brass tubes 6 feet long, which are equal to 109 square feet heating surface, making a total of 130 square feet, and with this heating surface it has been proved in practice that steam can be supplied to the cylinders to meet any requirements such locomotive of this

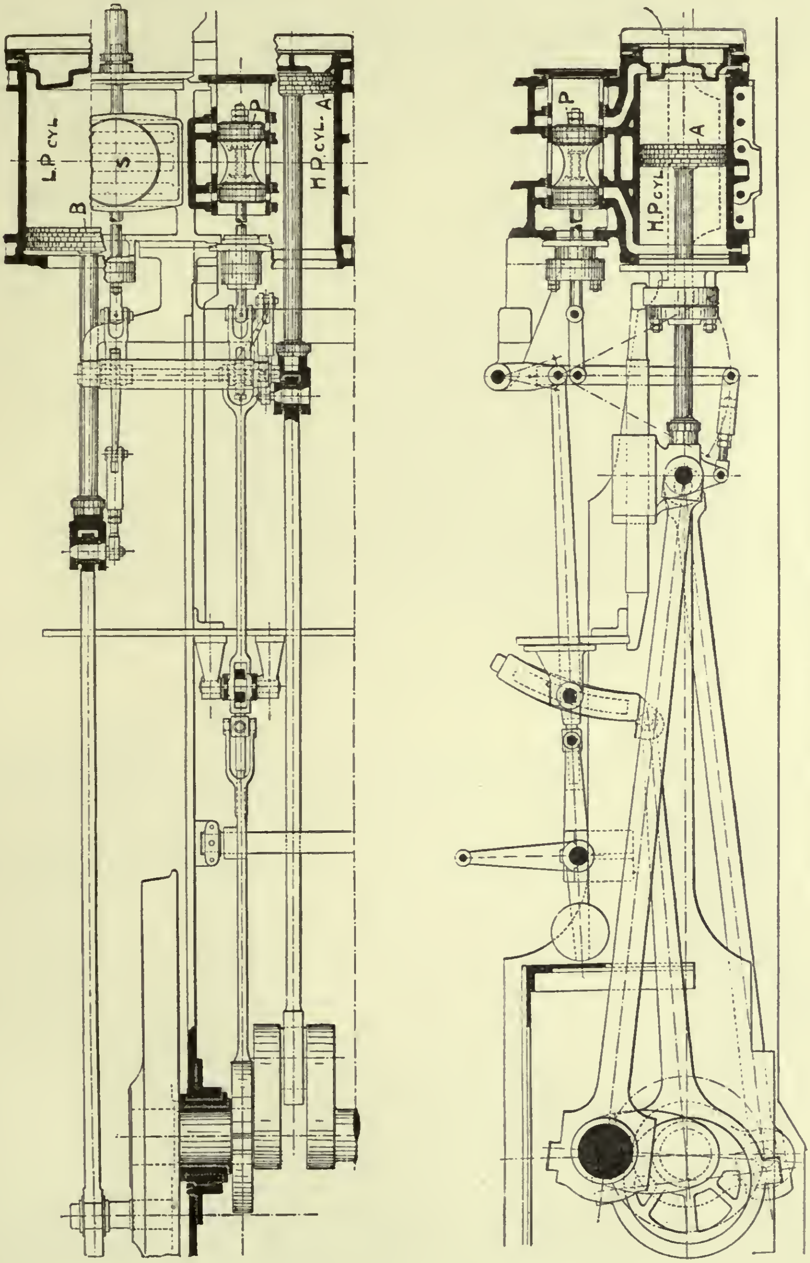


FIG. 210.—Cylinders, Pistons, Valves, and Valve Gear of Express Locomotive.

size can be put to. The capacity of the water tank is 160 gallons, and 6 cwt. of coal can be carried in the bunkers. The net weight of the locomotive is $6\frac{1}{2}$ tons, and in working order $7\frac{3}{4}$ tons. The safety valve is of the Ramsbottom pattern. Working pressure of steam, 130 lbs. per square inch. The external valve gear is shown in Fig. 213, a modification of Joy's valve gearing.

Another form of gearing for small locomotives, in which the whole engines are outside and easily get-at-able, is shown in the small crane locomotive of M. Borsig (Fig. 214). This gear is a modification of the common Stephenson link motion, the eccentrics being carried on an extension of the shaft.

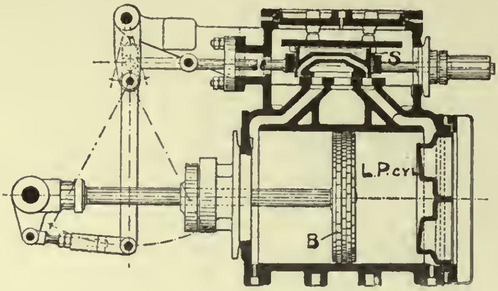


FIG. 211.—Low-Pressure Valve and Gear.

A steam motor car (Fig. 215) for a suburban railway has been running for some time past on the Cardiff, Penarth, and Cadogan section of the Taff Vale Railway. It has proved capable of running up gradients of 1 in 40 with ease under its full load. It is constructed to carry twelve first-class and forty third-class passengers, and there is also a luggage compartment. The first-class compartment is furnished with longitudinal seats. The third-class compartment is furnished with transverse seats arranged in pairs, divided by a central

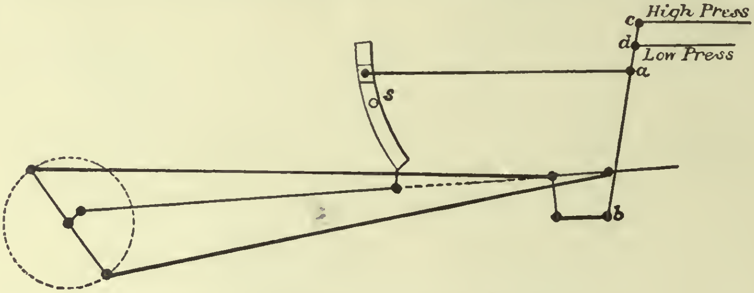


FIG. 212.—Diagram of Borries' Valve Gear.

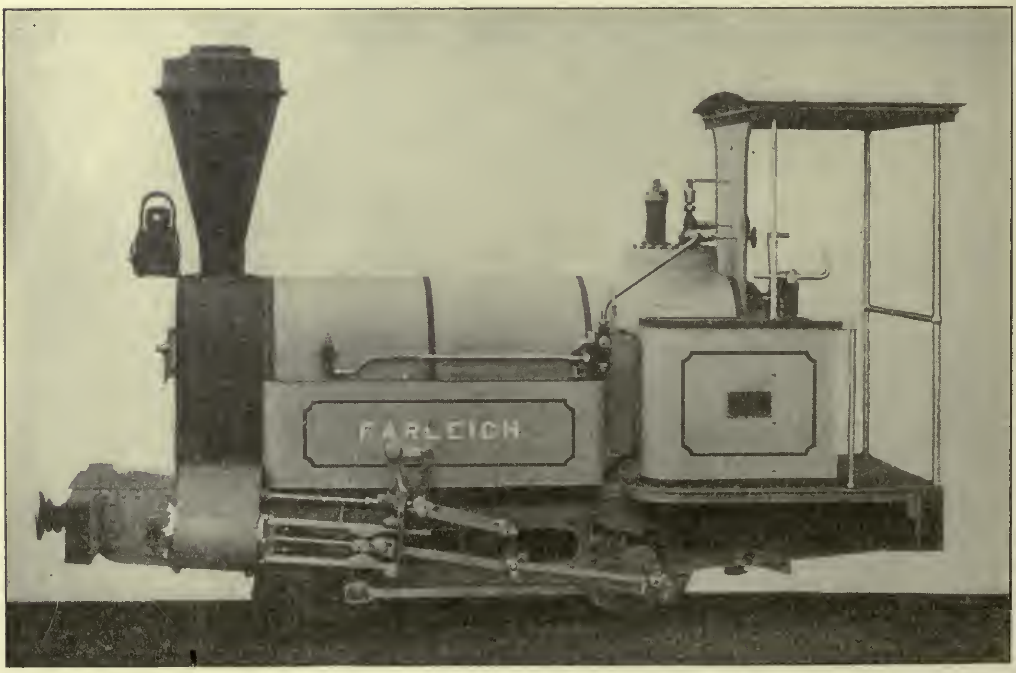


FIG. 213.—Light Railway Locomotive.

gangway. The car underframe is constructed of steel, and is carried at one end on an ordinary carriage bogie, the wheels of which are Kitson's patent wood cushioned type; the other end of the car is carried on the engine.

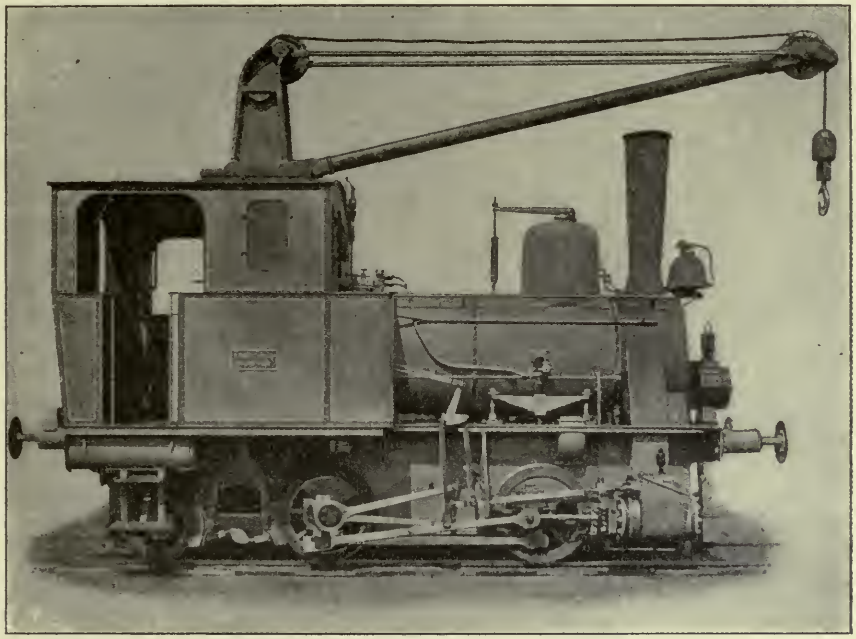


FIG. 214.—Continental Crane Locomotive.

The principal dimensions are:—

	Ft.	In.
Length of carriage body	45	0
Width of carriage body (outside)	8	6
Length of third-class compartment (inside)	26	1½
,, first-class compartment (inside)	8	11
Width of gangways	2	8
Height from floor to roof	7	2½
Wheel base of carriage-bogie	8	0
Diameter of wheels	2	10
Total length of car over buffers	58	9
Distance between centres of bogies	40	9½
,, longitudinally between inside pairs of wheels	32	9½
Total wheel base	49	3½
,, weight	33 tons 2 cwt.	

The engine is fitted with a boiler of the multitubular type, constructed of steel plates, with a copper fire box; the boiler contains 312 tubes 1¾ inches in diameter. The cylinders are fixed between the wheels and outside of the frame, and the connecting rod is coupled to the end pair of wheels. The valve gear is worked by ordinary eccentrics fitted on the driving axle inside of the frame, and actuates the valves on top of the cylinders by means of a rocking shaft. The link motion is of the Stephenson type, and the engine is reversed by a screw-reversing gear. Steam and hand brakes are provided.

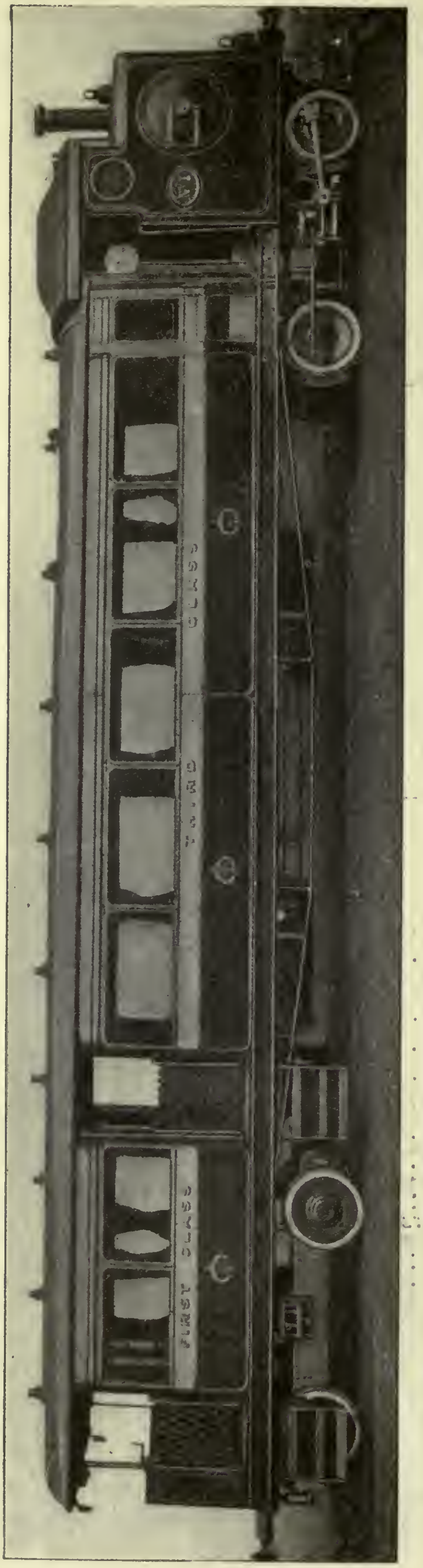


Fig. 215.—Steam Railway Motor Car.

The principal dimensions of the engine are as follow:—

Boiler—	Sq. Ft.
Fire grate area	8
Heating surface (fire box)	39
,, ,, (tubes)	299.5
Total	338.5

Engine—

Cylinders	9 in. in diam. by 14 in. stroke.
Wheel base	8 ft. 6 in.
Diameter of wheels	2 ,, 10 ,,

The capacity of the tanks is 530 gallons, and the capacity of the coal bunker is 10 cwt. The working pressure in the boiler is 160 lb. per square inch, and the tractive power is 4263.29 lb., taken at 80 per cent. of the working pressure.

To ensure proper control of the car when the engine is at the rear end, the guard can communicate with the driver by means of an electric bell, shut off steam, and sound the whistle, and also apply a hand brake on the carriage bogie.

The car has been built to the designs of Mr. T. Hurry Riches, M.Inst.C.E., locomotive engineer to the Taff Vale Railway Company.

The engines of a Riel autocar for the Paris-Lyons Railway are shown in Fig. 216 in detail in section; they are compound engines.

Diameter of high-pressure cylinders	5.51 in.
,, low-pressure cylinders	7.87 ,,
Stroke	7.87 ,,

The engine is bolted to four gusset plates riveted to the underframe. It drives the car by chain transmission, the chain wheels on the crank shaft being 14.17 inches in diameter, while those on the driving axle have a diameter of 21.26 inches. The wheels are 36.61 inches in diameter, and in order to attain a speed of 37.3 miles an hour the engine has to run at 514 revolutions. The chains and the engine are enclosed in a dust-proof casing.

These motor cars have been built for passenger traffic on the branch line from Alais to Port l'Ardoise, on which they have been tested, with good results. A motor car in full working order, weighing therefore 23.8 tons, was first run alone; subsequently it was made to haul one and then two 14-ton trailers. The line is 36 miles in length, with numerous curves 1310 feet and 1640 feet in radius, and gradients of 1 in 56 and 1 in 50. With the motor car alone, running at a medium speed, a boiler pressure between 113 lbs. to 142 lbs. per square inch was sufficient; the coke consumption amounted to no more than 9.5 lbs. per mile, and the water evaporated was 4.5 per lb. of coke. When the car hauled a trailer and ran at the same medium speed, the boiler pressure had to be raised on an average to 200 lbs. per square inch, the coke consumption being 10 lbs. per mile, and the water evaporation 4.9 per lb. of coke. With two 14-ton trailers, and running at medium speed, the coke consumption was 13.8 lb. per mile, and the water evaporation same as before. When running at high speed, the boiler pressure becomes very unsteady. Thus, with the motor car working alone, the pressure is constantly oscillating from 113 to 284 lbs. per square inch. The average coke consumption is 15.2 lbs. per mile.

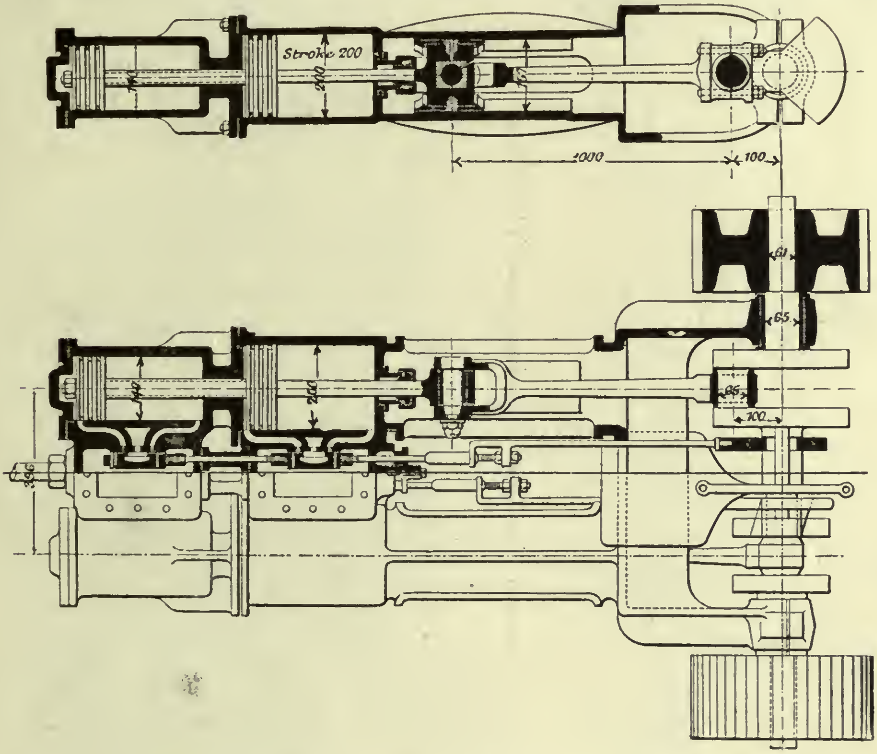


Fig. 216.—Sectional Elevation and Plan of Engines for Steam Railway Motor Car.

The American Locomotive Company's engines, the cylinders of which are shown in Figs. 192 and 193, have a bypass valve which acts as a safety valve against excessive pressure in the cylinder. The valve chamber end of these valves being of larger area than their cylinder ends, they remain closed under normal running conditions, but if through any cause the pressure should rise above the safe point it is relieved through these valves. Again, when the engine is drifting, the bypass automatically opens communication between the two ends of the cylinder, equalising the pressures. Piston valves are becoming almost universally in use in American practice.

The valve motion gearing is shown in Fig. 217.

The use of the piston valve and the obvious location of the valve chamber in the

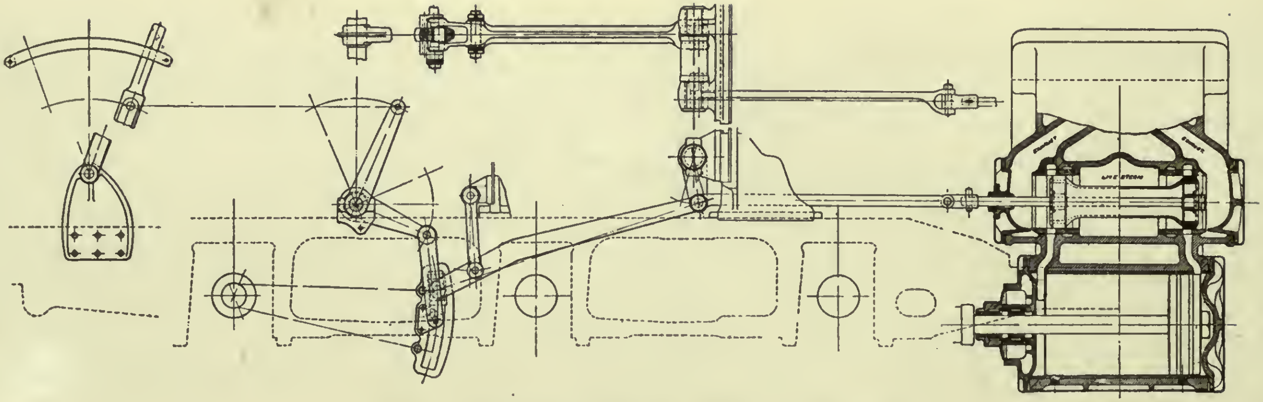


FIG. 217.—American Locomotive Company's Valve Gear.

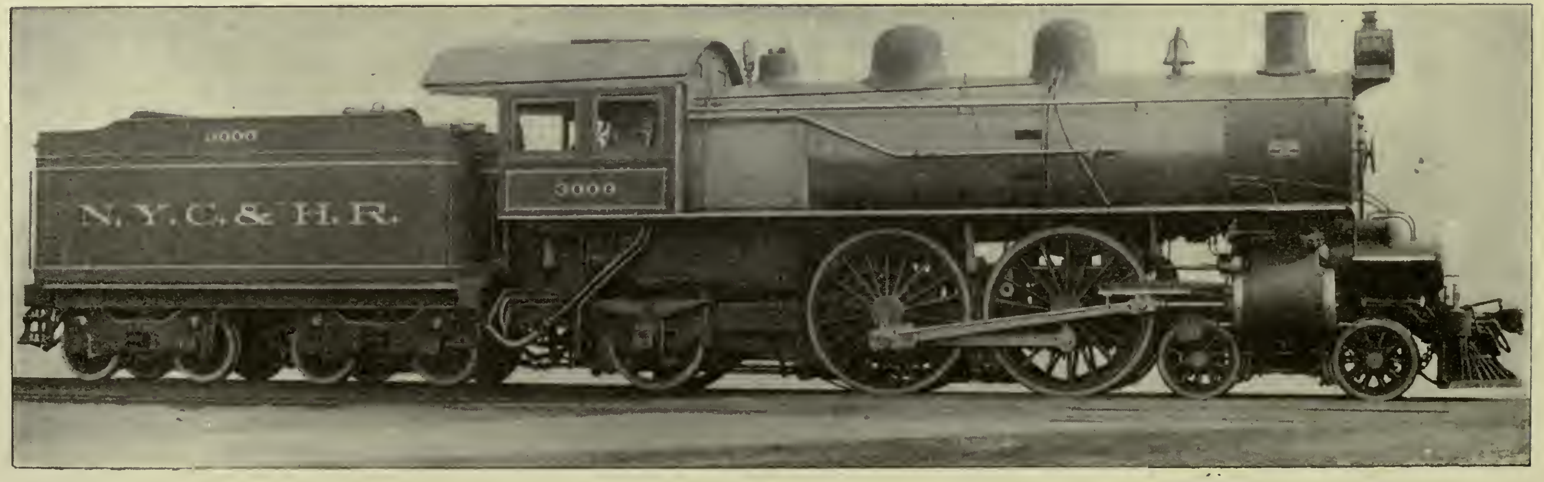


FIG. 218.—Four-Cylinder Balanced Compound Locomotive.

cylinder saddle, permit the use of the direct valve motion shown in the illustration; the central suspension feature, in combination with the very direct connections, justifies the name. The old double-ended rocker has been eliminated, and the motion work being wholly within the frames, the wheels may be spaced and arranged without reference to the rocker.

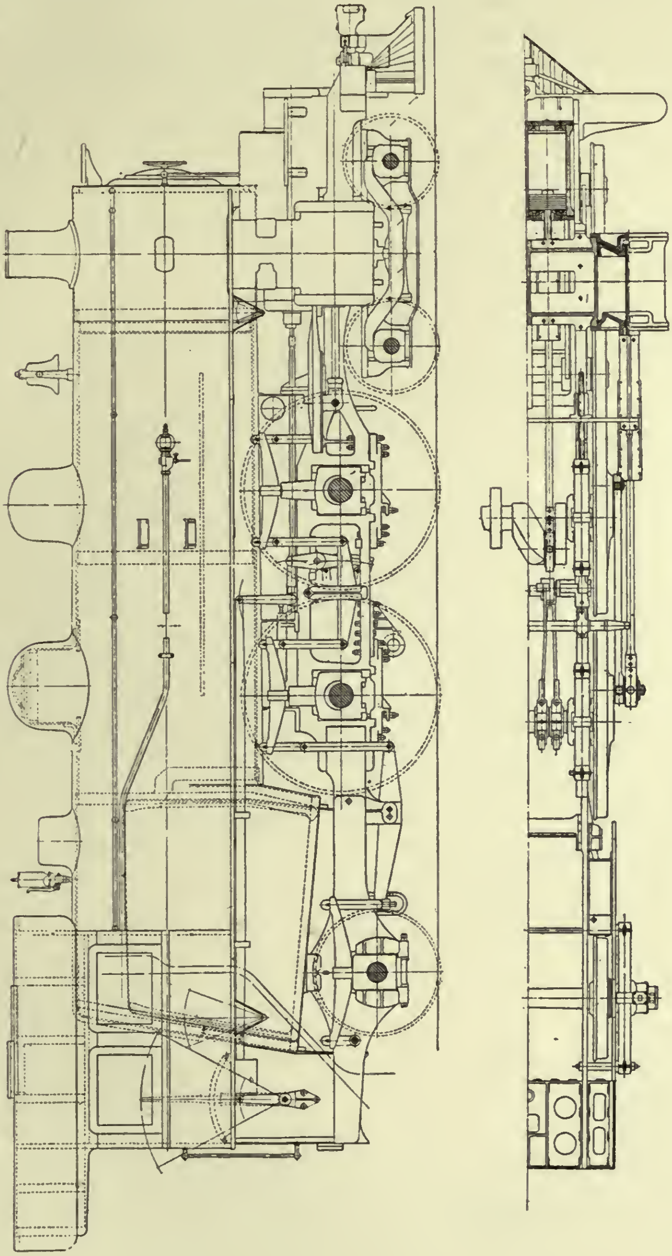


Fig. 219.—Elevation and Plan of 4-Cylinder Balanced Compound Locomotive.

Two-cylinder cross compounds have been largely used in passenger service, and 4-cylinder tandem compounds in freight service. In both the reciprocating parts have, with the gradual increase in the size of locomotives, become very heavy, and driving-wheel counterbalances have been increased to correspond. This increase of counterbalance, while improving the horizontal balance, has simply aggravated the troubles which result from imperfect vertical balancing, and they have been still more seriously affected by the great increase in speed, required especially in passenger locomotives. The use of four cylinders, arranged in pairs, so related and connected that the pistons of each pair are always moving in opposite directions, and with reciprocating parts so proportioned that they are approximately of the same weight, makes it possible to either eliminate all counterbalance from the driving wheels or reduce it to an inconsiderable minimum. This idea has been embodied in several designs, notably the De Glehn engine, which has been largely and successfully used in passenger service in France. In that engine the separate location of the two sets of cylinders makes it necessary to provide two complete valve motion mechanisms, one being outside the frames and the other inside. This requires the use of motions of two different types, which are not interchangeable. In the engine shown (in Fig. 218 a complete view and Fig. 219 an elevation and plan) the four cylinders are in a group in the usual place, and are so related that it has not been necessary to duplicate the valve motion or to depart in any way from the best previous accepted practice.

The use of four cylinders, two high-pressure and two low-pressure, gives an opportunity for compounding under the most favourable conditions, and with each high-pressure piston working 180 degrees from its low-pressure piston, and the other pair working 90 degrees from the first pair, the successive impulses from the four cylinders produce a remarkably uniform turning moment. This results in a much more rapid rate of acceleration when starting up than has been possible with 2-cylinder engines or with many previous types of 4-cylinder engines.

In order to avoid the concentration of work on a single driving axle, it has been considered best to connect one pair of cylinders to the forward axle and the other pair to the rear axle. This is accomplished by placing the high-pressure cylinders between the frames and locating them slightly in advance of the usual position, so as to secure the necessary length of space for the connections, cross-heads, guides, connecting rods, etc. The forward axle is necessarily a crank axle. The low-pressure cylinders are placed outside and connected in the usual way to crank pins on the rear drivers.

With this relative arrangement of each pair of one high-pressure and one low-pressure cylinders it has been possible to apply both a high-pressure and a low-pressure piston valve to the same valve stem, and to utilize the intermediate portion of the valve chamber as a receiver between the 2-cylinder. This engine, No. 3000 (Fig. 218), is the only locomotive which maintained a speed of 75 miles (320 revolutions of the driving wheels per minute) for one hour on the testing plant at the St. Louis Exposition. The following table gives the general dimensions:—

General Dimensions

Gauge of track	4 feet 8½ inches.
LOADED WEIGHTS—	
On leading truck	50,000 lbs.
On driving wheels	110,000 ,,
On trailing truck	40,000 ,,
Total engine	200,000 ,,
Tender	122,500 ,,
WHEEL BASE—	
Driving	7 feet
Total of engine	27 feet 9 inches.
,, ,, and tender	53 ,, 8 ,,

CYLINDERS—

Diameter	15½ and 26 inches.
Stroke of piston	26 ,,
Valves, piston type.	

WHEELS—

Diameter of engine truck wheel	36 inches.
,, driving wheels, outside	79 ,,
,, trailing wheels	50 ,,
,, tender wheels	36 ,,

JOURNALS—DIAMETER AND LENGTH—

Engine truck	6½ by 12 inches.
Driving	10 ,, 12 ,,
Trailing	8 ,, 14 ,,
Tender	5½ ,, 10 ,,

BOILER—

Type	straight.
Outside diameter at front end	72¼ inches.
Length of fire box, inside	96⅛ ,,
Width of fire box, inside	75¼ ,,
Number of tubes	390.
Diameter of tubes	2 inches.
Length of tubes	16 feet.
Working pressures per square inch	220 lbs.
Heating surface in tubes	3,248.1 square feet. Arch 23.0 ,,
,, ,, fire box	175 ,,
Total heating surface	3,446.1 ,,
Grate area	50.23 ,,

TENDER CAPACITY—

Water	6000 gallons.
Fuel	10 tons.

CLEARANCE LIMITATIONS—

Height of stack above rail	14 feet 10 inches.
Width	10 feet.
Length over all	62 feet 2¾ inches.
Maximum tractive power	27,500 lbs.

In developing locomotives of large hauling capacity, as required on steep grades, many limitations are imposed if conventional types are adhered to, due to restrictions regarding clearances, wheel base, weight per running foot or per axle. If the weight per running foot is limited, the only way to secure increased total weight and power is by lengthening the rigid wheel base and total wheel base. This results in increased friction when passing through curves, and increased wear and tear on both engine and track. Moreover, in engines of usual types a considerable percentage of weight is carried by trucks and is not available for traction.

In endeavouring to escape from these limitations designers have resorted to the

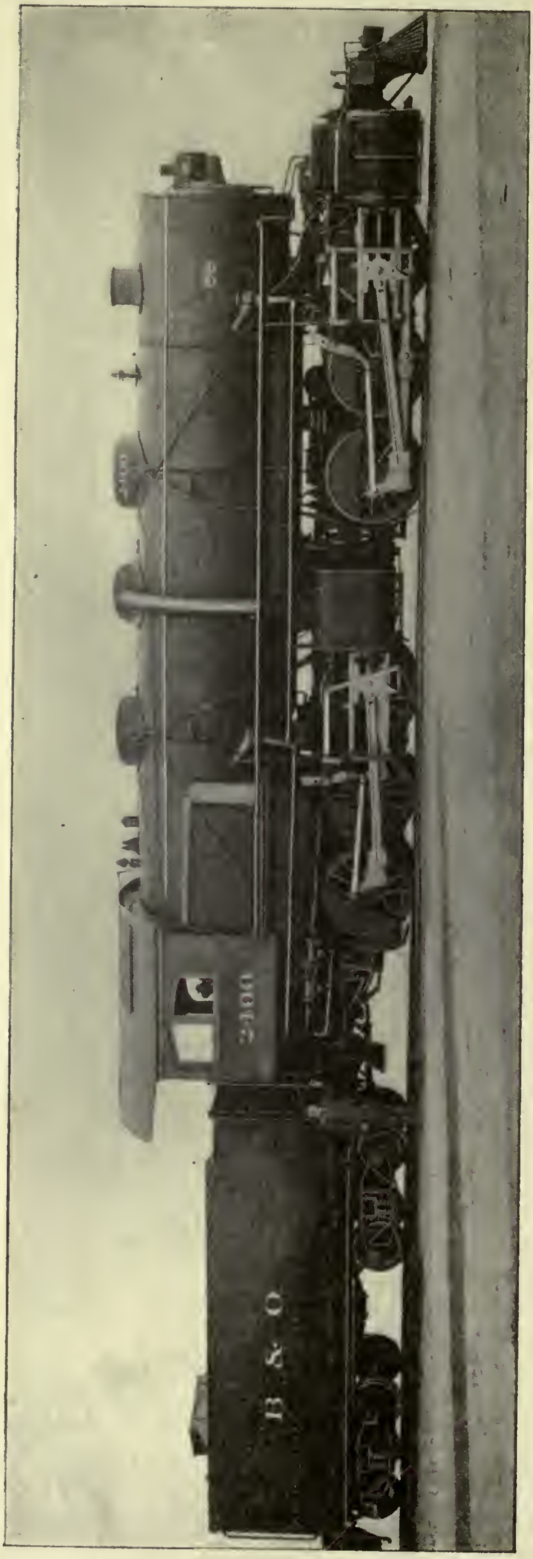


FIG. 220.—Mallet Articulated Compound Locomotive.

expedient of introducing two separate engines under the same boiler. The Fairlie engine in England was of this general type, both engines, however, being mounted on swivel trucks. In Austria, later, the design was improved by making one truck rigid and only one swivelling. Still later the engine was so greatly improved by Mallet, the French locomotive designer, as to be given his name. A large number of Mallet articulated compounds have been put in use on European roads having heavy grades and sharp curves. This type of engine permits compounding under the most advantageous conditions, as the high-pressure cylinders can be applied to one truck and the low-pressure cylinders to the other, and any desired cylinder ratios can be adopted. This divides the work equally between the two sides of the engine, and the retardation of cut-off peculiar to the compound system gives a more nearly uniform turning moment.

In the engine shown in Fig. 220 complete, and in Fig. 221 in elevation and plan of this type, each pair of cylinders is connected with three pairs of driving wheels, the rear high-pressure group being rigidly attached to the boiler, while the forward or low-pressure group is on a swivelling frame, the motion of which about its centre is duly restrained by springs, which also tend to bring the forward group of wheels into proper alignment when the engine enters a tangent. The wheel base of each group of three pairs of driving wheels is 10 feet, and total wheel base of the engine is 30 feet 8 inches. The total weight of the engine in working order is 334,500 lbs., or slightly over 10,900 lbs. per running foot of wheel base. The normal tractive power when running compound is about 70,000 lbs., but this can be increased (by running the engine simple) to 85,000 lbs.

Steam pipes from the dome are led down the outside of the boiler to

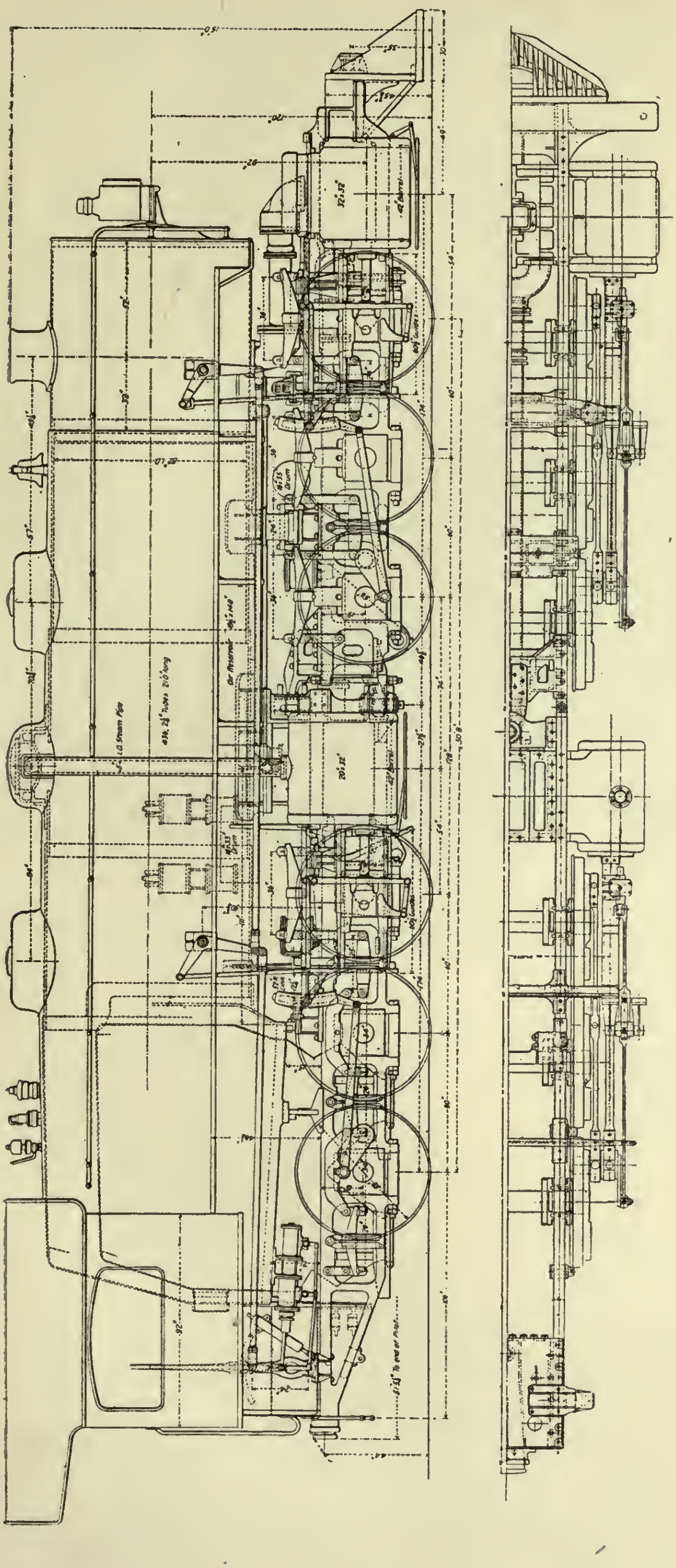


FIG. 221.—Elevation and Plan of Mallet Articulated Compound Locomotive.

the high-pressure steam chest. The high-pressure exhaust is led to a receiver located between the high-pressure cylinders and thence by a pipe (fitted with swivel and expansion joints) to the cylinder saddle of the forward or low-pressure engine, the cylinders of which exhaust (through a swivel pipe connection) to the smoke box as usual.

The high-pressure engine has piston valves, the low-pressure engine has slide valves. Both are fitted with the Waalschaert outside valve gear. The reversed lever is arranged to be operated either by hand or by compressed air as preferred. The high-pressure cylinders are provided with intercepting, reducing, and high-pressure exhaust valves, permitting the use of live steam (at reduced pressure) in the low-pressure cylinders when circumstances require.

This engine can be operated on curves of twenty degrees and upwards with great ease, and with less frictional resistance than an ordinary consolidation engine of half its capacity. It is undoubtedly the largest and most powerful locomotive in the world at the present time, while many of its parts are lighter than in many ordinary heavy locomotives.

The following are the general dimensions :—

Gauge of track	4 feet 8½ inches.

LOADED WEIGHTS—

On leading truck	
On driving wheels	334,500 lbs.
On trailing truck	
Total engine	334,500 lbs.
Tender	143,000 lbs.

WHEEL BASE—

Driving	10 and 10 feet.
Total of engine	30 feet 8 inches.
,, ,, and tender	64 ,, 7 ,,

CYLINDERS—

Diameter	20 and 32 inches.
Stroke of piston	32 ,,

Valves, H.-P. piston, L.-P. slide.

WHEELS—

Diameter of engine truck wheels	
,, driving wheels, outside	56 inches.
,, trailing wheel	
,, tender wheels	33 inches.

JOURNALS—DIAMETER AND LENGTH—

Engine truck	
Driving	9 by 13 inches.
Trailing	
Tender	5½ by 10 inches.

BOILER—

Type	straight top, radial stay.
Outside diameter at front end	84 inches.
Length of fire box, inside	108 ,,
Width of fire box, inside	96 ,,
Number of tubes	436.
Diameter of tubes	2¼ inches.
Length of tubes	21 feet.
Working pressure per square inch	235 lbs.
Heating surface in tubes	5,366.3 square feet.
,, ,, fire box	219.4 ,,
Total heating surface	5,585.7 ,,
Grate area	72.2 ,,

TENDER CAPACITY—

Water	7,000 gallons.
Fuel	13 tons.

CLEARANCE LIMITATIONS—	
Height of stack above rail	15 feet.
Width	10 feet 5 inches.
Length over all	79 ,, 6½ ,,
Maximum tractive power	71,500 lbs.

Working Compound.

Fig. 222 represents a small saddle tank locomotive of the American Company's make. The bell is to be found on most locomotives in America, in order to warn the public of their approach to a town or city. Many lines of railway run right through towns on the street levels. The particulars of this locomotive are as follow :—

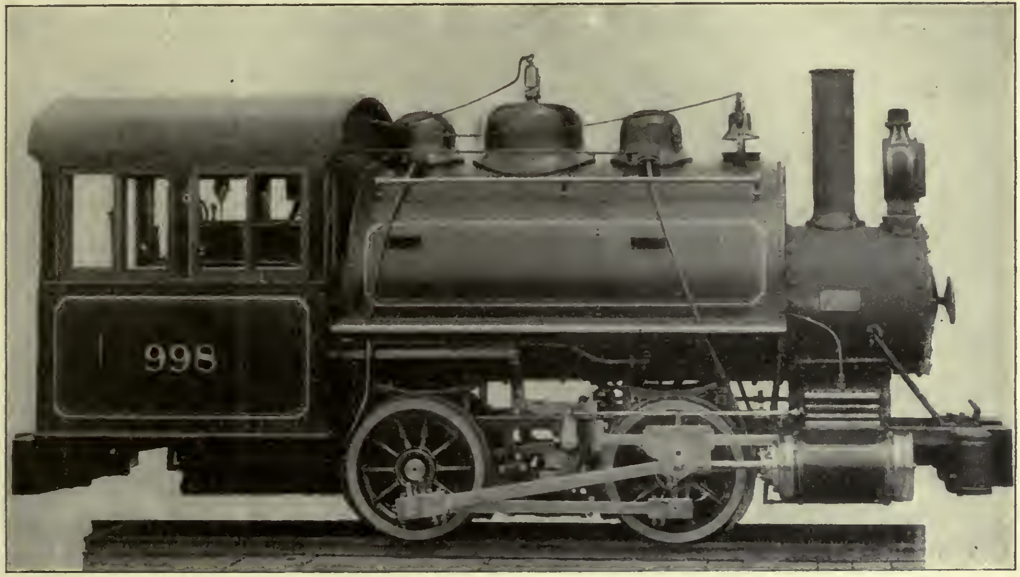


FIG. 222.—American Saddle Tank Locomotive.

GENERAL DIMENSIONS

Gauge of track	3 feet.
LOADED WEIGHTS—	
On leading truck	
On driving wheels	30,900 lbs.
On trailing truck	
Total engine	30,900 lbs.
Tender	
WHEEL BASE—	
Driving	5 feet.
Total of engine	5 ,,
,, ,, and tender	5 ,,
CYLINDERS—	
Diameter	10 inches.
Stroke of piston	16 ,,
Valves, slide type.	

WHEELS—

Diameter of engine truck wheel	
,, driving wheels, outside	33 inches
,, trailing wheels	
,, tender wheels	

JOURNALS—DIAMETER AND LENGTH—

Engine truck	
Driving	5 by 6 inches
Trailing	
Tender	

BOILER—

Type	straight top.
Outside diameter at front end	34 inches.
Length of fire box, inside	$41\frac{7}{8}$,,
Width of fire box, inside	24 ,,
Number of tubes	94.
Diameter of tubes	$1\frac{1}{2}$ inches.
Length of tubes	8 feet $2\frac{3}{4}$,,
Working pressure per square inch	150 lbs.
Heating surface in tubes	303.4 square feet.
,, ,, fire box	39 ,,
Total heating surface	342.4 ,,
Grate area	7 ,,

TENDER CAPACITY—

Water	400 gallons.
Fuel	$\frac{1}{2}$ ton.

CLEARANCE LIMITATIONS—

Height of stack above rail	9 feet 4 inches.
Width	6 ,, 11 ,,
Length over all	19 ,, 6 ,,
Maximum tractive power	6,180 lbs

THE BALDWIN LOCOMOTIVES.

These locomotives are made in all types; the 4-cylinder compound locomotive is most interesting. A steam consumption of 22.86 lbs. per indicated horse-power per hour has been attained, a result highly creditable.

The prevailing conditions in railroad passenger traffic demand the highest practicable rate of speed with the heaviest possible load. Trains with loads of from 300 to 600 tons behind the engine are required to attain a sustained speed of at least fifty miles per hour, and those of 200 to 300 tons a speed of sixty miles per hour. Instances may be cited where, in order to maintain the schedule time, it is necessary to cover a distance of nearly forty miles, on comparatively level track, at a speed of eighty miles per hour, and this, not for one day but every day in the year.

That a single-expansion locomotive, properly designed, can do this work is not denied; but experience has shown that the dead weight required for such a locomotive, the increased strains and internal friction, together with the difficulty in properly counterbalancing the driving wheels, is liable to make the wear and tear on the track excessive. Aside from these difficulties the firing of the locomotive under such conditions becomes a question of moment, as it is practically impossible for one man to handle the necessary amount of coal to keep up the requisite steam.

The advantages that are obtained from compounding the steam used in a locomotive are well known, but they may be briefly stated as follows :—

1. Greater efficiency of boiler, for the reason that proportionately less steam is used than in single expansion, and a less rate of evaporation is required.

2. A lighter final exhaust to the stack, by which means a more complete and slower rate of combustion is maintained.

3. A higher boiler pressure can be advantageously used, and consequently drier steam obtained.

4. A greater range of expansion is obtained, because the initial pressure is higher and the exhaust pressure is lower than in single-expansion cylinders. As the expansion is divided between two cylinders, the relative temperature of the two will be higher and result in decreased cylinder condensation.

All of these advantages tend to an economy in the use of fuel and water, which reaches to from 15 to 25 per cent., depending on the conditions of service. It has been maintained by some that the increased cost of repairs in the present types of compound locomotives more than offsets the amount saved by fuel economy. This criticism has led to further improvements, and the whole problem is solved by the introduction of the 4-cylinder balanced compound locomotive (Fig. 223), designed and built by the Baldwin Locomotive Works. In this design all the advantages of compounding are retained and many of the disadvantages eliminated. In addition a means is provided whereby a complete balance of both the revolving and reciprocating parts is obtained.

The first locomotive of the 4-cylinder balanced compound system was built in January 1902.

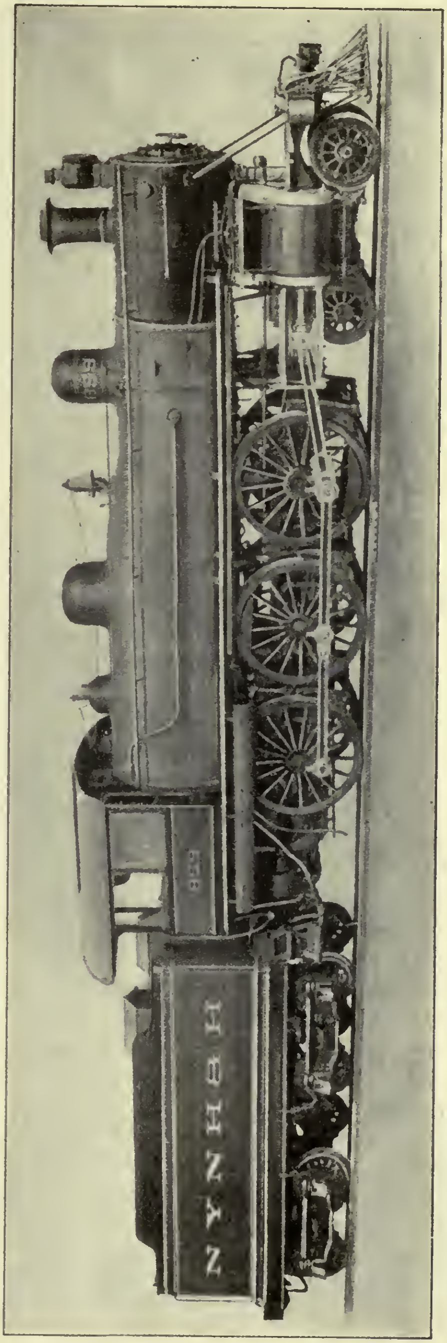


FIG. 223.—Four-Cylinder Balanced Compound Locomotive.

As is common to locomotives of this system, the low-pressure cylinders are placed outside the engine frames, connections being made with crank pins on the driving wheels. This is to avoid stressing the crank axle by the heavy pressure in the low-pressure cylinders in starting. The high-pressure cylinders are located inside the frames in the same horizontal plane as the low-pressure, and connection is made with a crank-driving axle. In the locomotive referred to above all four connecting rods are coupled with the front axle.

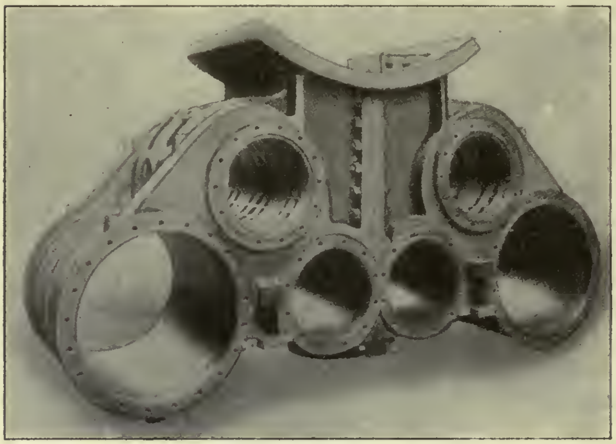


Fig. 224.—Cylinder Castings.

The cylinder saddle is cast in two parts and bolted together in the usual way (Fig. 224), each half containing a high and low-pressure cylinder and a single valve which controls the admission of steam to both cylinders. This admits of the use of the ordinary Stephenson type of valve motion, the same as is used in single-expansion locomotives. The valve (Fig. 225) is of the piston type with central steam admission, and slides in a machined bushing (Fig. 226), which is forced into the cylinder saddle. A single reverse lever in the cab is all that is required.

The course of the steam from its admission to the high-pressure cylinder until the final exhaust is shown by the accompanying diagram (Fig. 227).

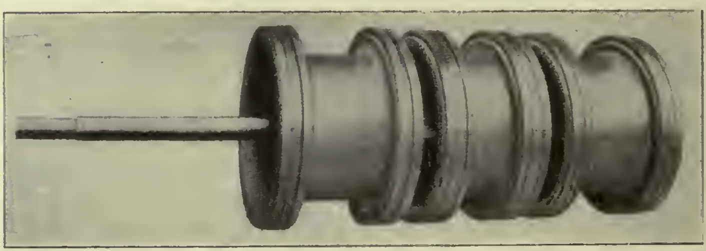


Fig. 225.—Piston Valve.

The live steam port in this design is centrally located between the induction ports of the high-pressure cylinder. Steam enters the high-pressure cylinder through the steam port and the central external cavity in the valve. The exhaust from the high-pressure cylinders takes place through the opposite steam port to the interior of the valve, which acts as a receiver. The outer edges of the valve control the admission of steam to the low-pressure cylinder. The steam passes from the front of the high-pressure cylinder through the valve to the front of the low-pressure cylinder, or from the back of the high-pressure to the back of the low-pressure cylinder. The exhaust from the low-pressure cylinder takes place through external cavities under the front and back portion of the valve, which communicate with the final exhaust port. The starting valve connects the two live steam ports of the high-pressure cylinder, to allow the steam to pass over the piston.

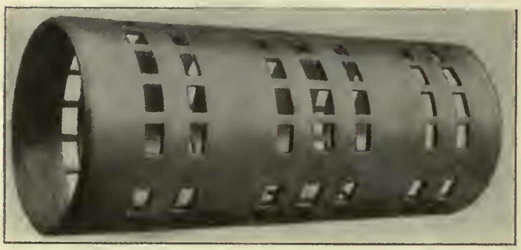


Fig. 226.—Valve Bushing.

The diagram (Fig. 231) show a side elevation and plan of the Baldwin valve motion.

The balanced system of locomotives requires the use of a crank axle, but in view of the fact that this style of axle is successfully used in foreign locomotive practice, it is reasonable to suppose that with the decrease in the strains brought about by the balanced compound principle, the prejudice against the crank axle will be overcome. Every effort has been brought to bear to increase the strength of the axle and ensure satisfactory results. Two different designs have been used, one of these is shown in Fig. 229. It is of nickel steel and forged in one piece. The centre or neutral axes of the crank pins are drilled and a 4-inch steel pin is forced into the opening under hydraulic pressure and riveted over the cheeks. This gives increased strength and additional security in the event of the pin becoming cracked. A steel band is also shrunk around the outer surface of each cheek.

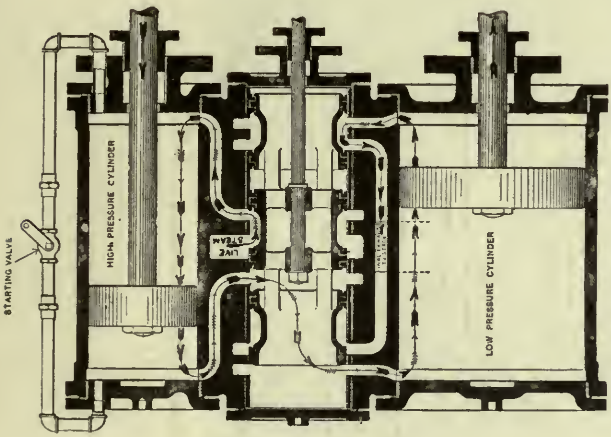


Fig. 227.—Cylinders, Pistons, and Valves of Baldwin Locomotive.

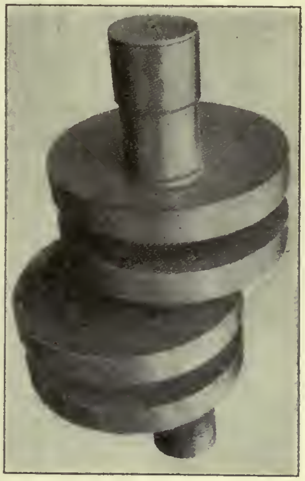


Fig. 228.—"Built-up" Disc Axle.

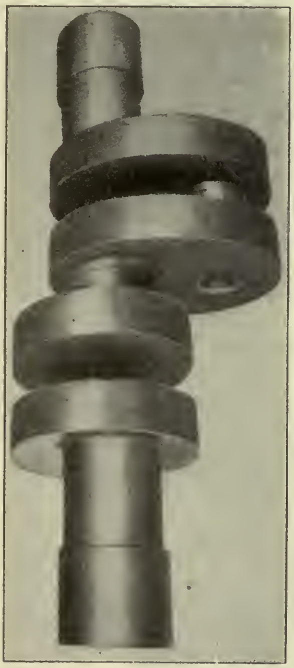


Fig. 229.—Crank Axle.

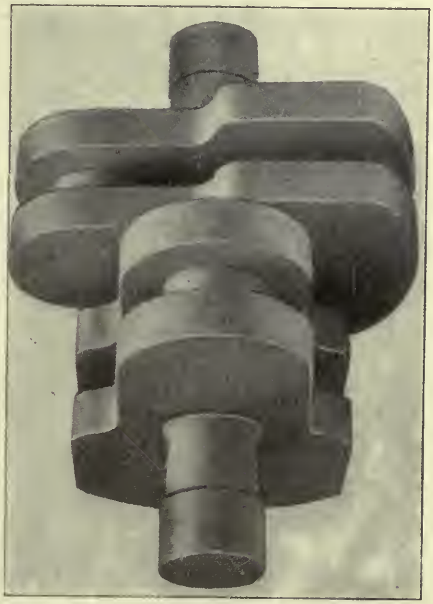


Fig. 230.—Built-up Axle. Weights Balanced in same Plane.

Another form of axle is that shown in the accompanying illustration (Fig. 228). This is what is termed the "built-up" disc axle. It is in nine pieces forged separately. They consist of the three parts of the axle proper, the four discs which form the cheeks, and

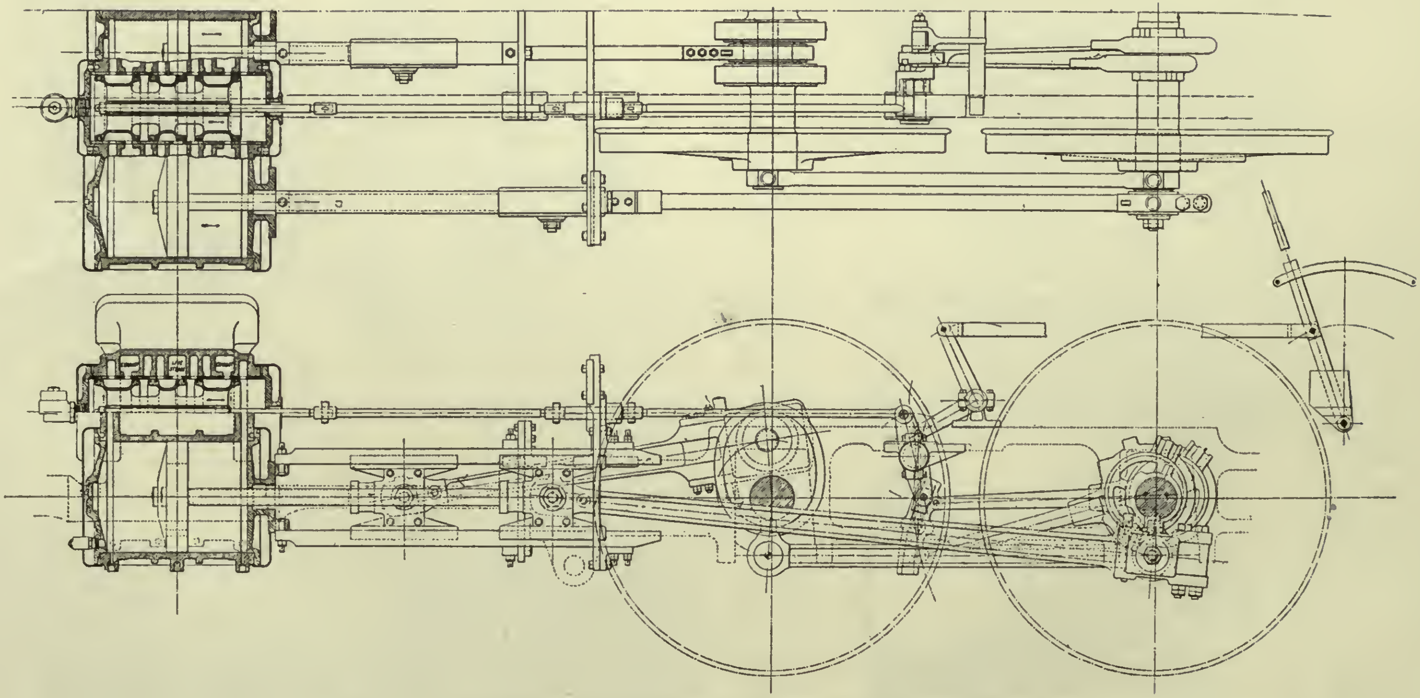


Fig. 231.—Sectional Plan and Elevation of Baldwin Locomotive Valve Gear.

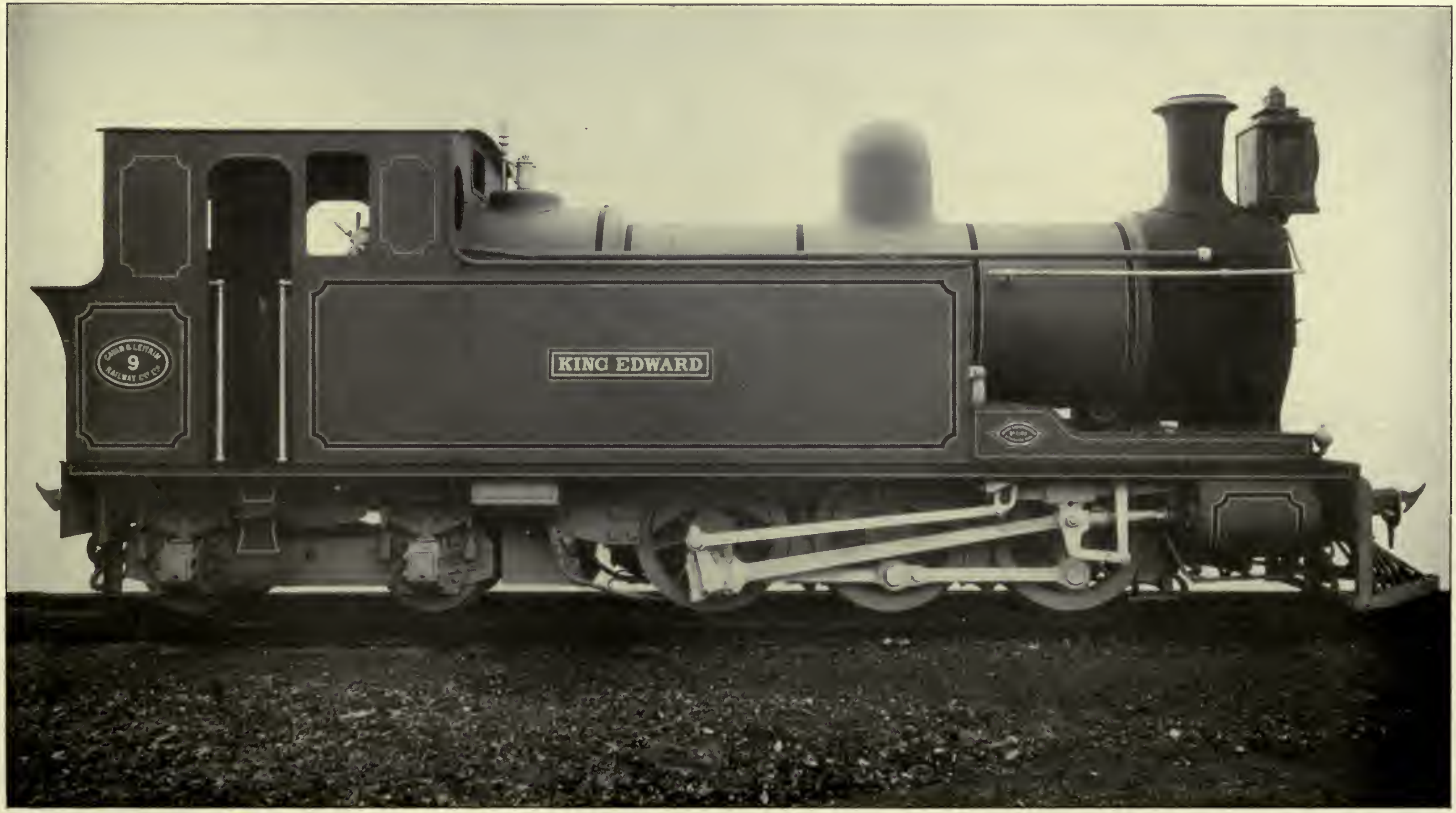

CAVAN & LEITRIM
9
RAILWAY CY LTD
KING EDWARD

Plate VII.—Powerful Narrow Gauge Tank Locomotive.

the two crank pins. Each of these parts is thoroughly forged, and after being machined they are forced together under a hydraulic pressure of 100 tons, keyed, and riveted over. This arrangement ensures the direction of the grain to suit the strains brought upon the axle. The illustration (Fig. 230) shows a built-up axle so designed that all the weights are balanced in the same plane. This type of axle is not stressed by the effect of the "whip" at high speeds, and there is likewise no gyroscopic effect by balancing different weights in the same plane. The following table gives the general dimensions of the locomotive shown in Fig. 223:—

General Dimensions

CYLINDERS—	
Diameter (high-pressure)	15 inches.
,, (low-pressure)	25 ,,
Stroke	26 ,,
Valve	balanced piston.
BOILER—	
Type	waggon top.
Material	steel.
Diameter	64 inches.
Thickness of sheets	$\frac{3}{4}$ and $\frac{11}{16}$ inch.
Working pressure	210 lbs.
Fuel	soft coal.
Staying	Radial.
FIRE BOX—	
Material	steel.
Length	96$\frac{1}{8}$ inches.
Width	66$\frac{1}{4}$,,
Depth (front)	70$\frac{3}{8}$,,
,, (back)	68$\frac{3}{8}$,,
Thickness of sheets, sides	$\frac{3}{8}$ inch.
,, ,, back	$\frac{3}{8}$,,
,, ,, crown	$\frac{3}{8}$,,
,, ,, tube	$\frac{1}{2}$,,
TRAILING WHEELS—	
Diameter	48 inches.
Journals	8 by 12 ,,
WHEEL BASE—	
Driving	7 feet 3 inches.
Rigid	15 ,, 6 ,,
Total engine	30 ,, 2 ,,
,, ,, and tender	57 ,, 7$\frac{1}{2}$,,
WEIGHT—	
On driving wheels	92,800 lbs.
On truck	56,800 ,,
On trailing wheels	46,900 ,,
Total engine	196,500 lbs.
Total engine and tender	280,000 lbs.

TANK—	
Capacity	6000 gallons.
TENDER—	
Number of wheels	8.
Diameter of wheels	37¼ inches.
Journals	5 by 9 ,,
SERVICE—	
Passenger.	
WATER SPACE—	
Front	4 inches.
Sides	4 ,,
Back	3 ,,
TUBES—	
Material	Iron.
Wire gauge	No. 11.
Number	274.
Diameter	2¼ inches.
Length	19 feet.
HEATING SURFACE—	
Fire box	155.5 square feet.
Tubes	3050.5 ,,
Firebrick tubes	6.27 ,,
Total	3212.27 ,,
Grate area	44.14 ,,
DRIVING WHEELS—	
Diameter outside	78 inches.
,, of centre	70 ,,
Journals (front)	10 by 10½ ,,
,, (back)	9½ by 12 ,,
ENGINE TRUCK WHEELS—	
Diameter	33 inches.
Journals	6 by 10 ,,

A steam road engine manufactured by Messrs. Clayton & Shuttleworth Limited, for His Majesty's Dockyard, Chatham, is shown in Fig. 232. The engine answers a threefold purpose. It acts as an ordinary road roller of 12½ tons weight, as a traction engine for hauling or driving machinery, and as a crane for lifting 3 tons and transporting the weight suspended. The engine itself is compound, the cylinders being placed side by side, and being 5½ inches and 9 inches diameter, with a 12-inch stroke. The cylinder casting is mounted on a planed seating. In the top cover of the cylinder, which is of considerable depth, the stop valve is placed. The engine is supplied with side-plates for hiding the working parts, a disc fly-wheel, an awning over the driver, and a steam pump, in addition to the ordinary pump. The hind rollers are 5 feet 7 inches diameter and 16 inches face; the front rollers are 3 feet 7 inches diameter and 2 feet 2 inches on

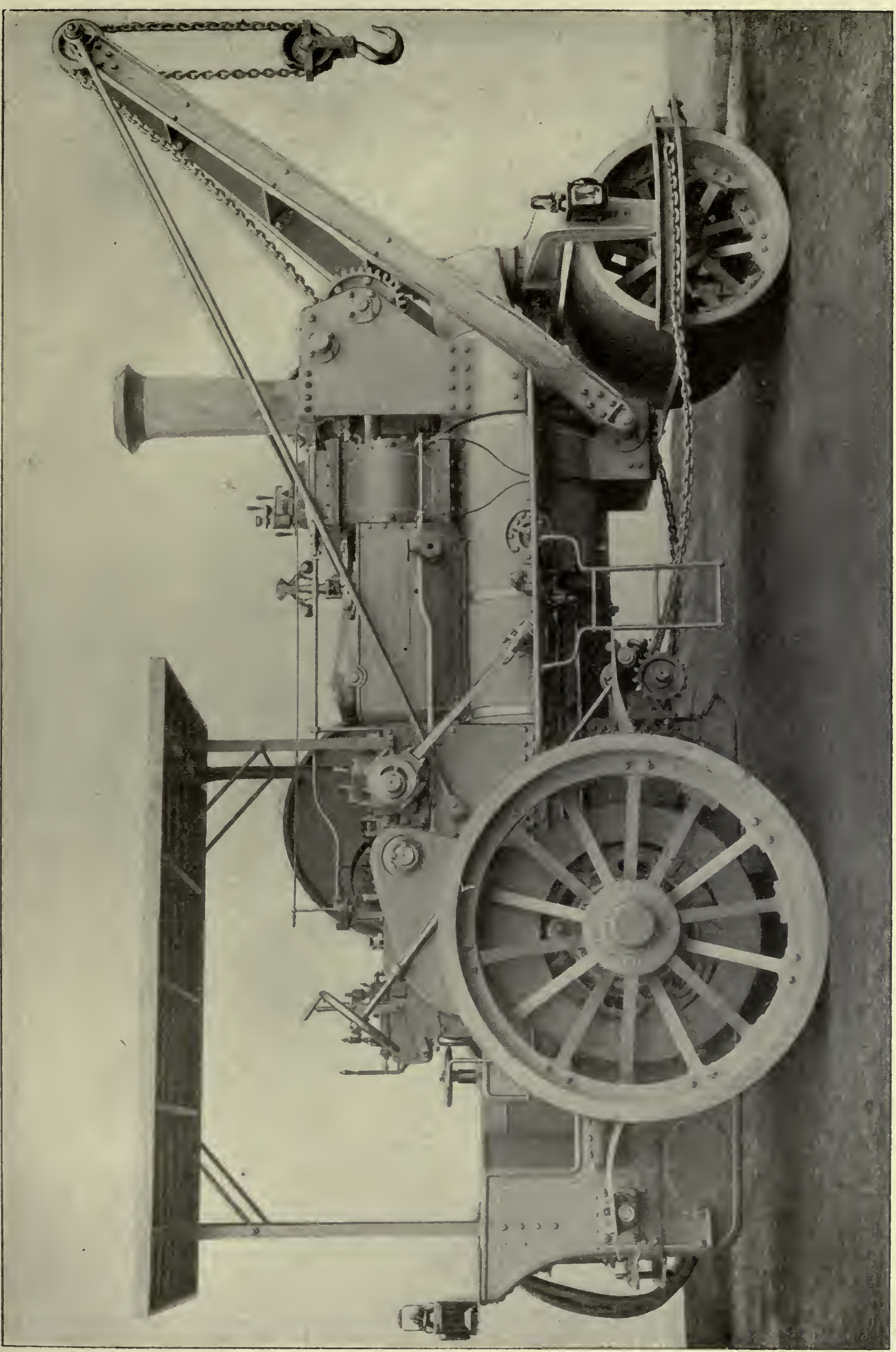


FIG. 232.—Convertible Road Roller and Traction Engine, with Crane.

face, or 4 feet 4 inches the two together; all the rollers are fitted with rims, which are easily renewable. Spring scrapers are fitted to the hind rollers, and adjustable scrapers to the front rollers. The roller parts can easily be removed and the traction engine details put in their place. The general arrangements will be readily seen from the engraving. The whole forms a strong serviceable piece of machinery.

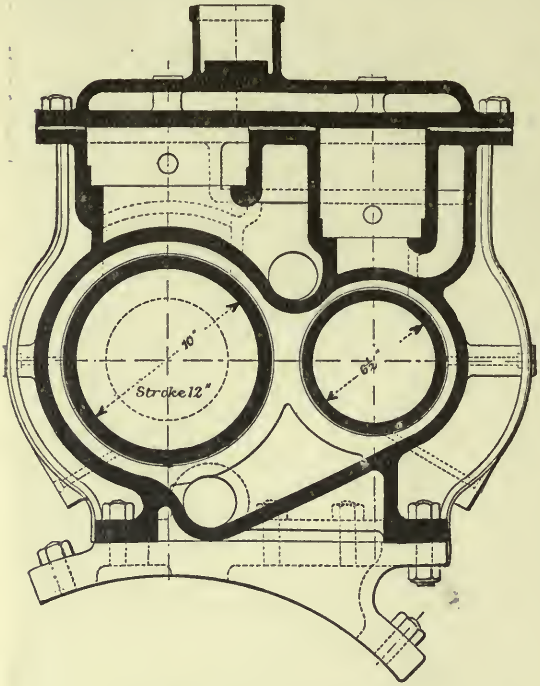


Fig. 233.—Transverse Section through Cylinders of Combination Traction Engine.

The high and low-pressure cylinders are placed side by side (Fig. 233); the slide valves are arranged above the cylinder liners. The slide valves are actuated by radial valve gear which produces an excellent distribution of steam to both cylinders. Eccentrics are dispensed with, this giving more room on the crank shaft for wide gearing for two or more travelling speeds inside the box brackets. High-pressure steam can be admitted to the low-pressure steam chest for starting, so that the engine for the time being will work the same as an ordinary double-cylinder engine.

Fig. 234 shows an elevation of the valve gear to scale of the patent compound road locomotive.

FIRELESS LOCOMOTIVES

In some cases where smoke and hot ashes or sparks are not permissible, locomotives propelled by compressed air or by steam stored with water at a high temperature are employed. Sometimes a solution of soda is used to store more heat than plain water.

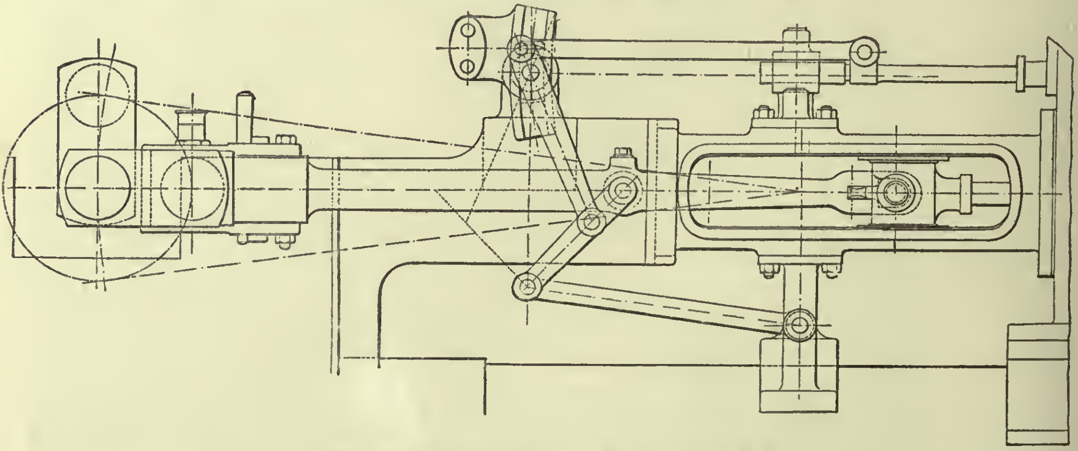


Fig. 234.—Elevation of Traction Engine Valve Gear.

A compressed-air locomotive is shown in Fig. 235, in elevation and plan. The air at a pressure of 1000 lbs. per square inch is stored in 27 steel tubes, containing in all about 70 cubic feet of air at that pressure. The air is supplied to the engine through a reducing valve at a pressure about 150 to 180 lbs. per square inch.

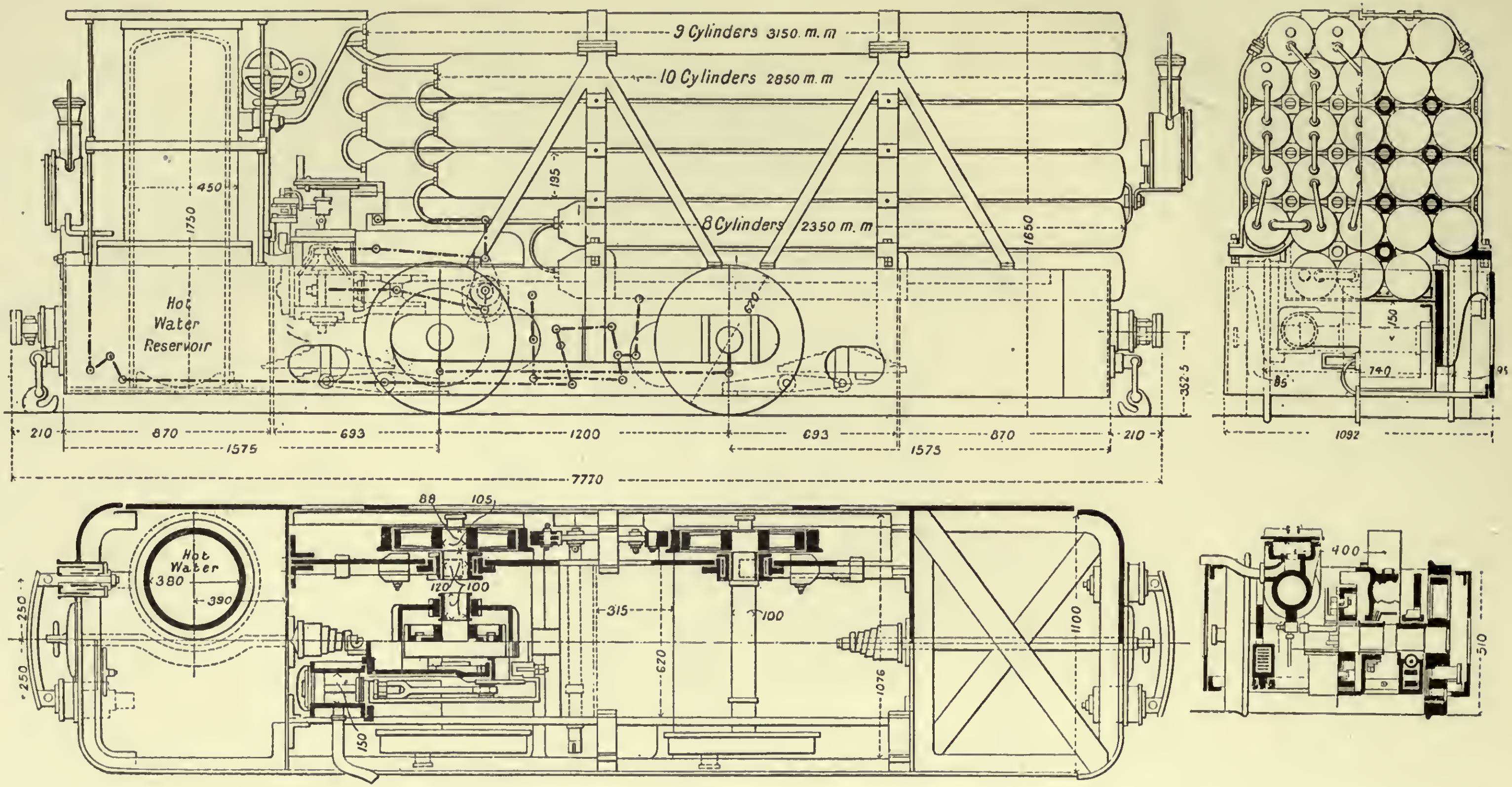

9 Cylinders 3150 m.m
10 Cylinders 2850 m.m
8 Cylinders 2350 m.m
Hot Water Reservoir
450
1750
195
1650
620
352.5
210
870
1575
693
1200
693
1575
870
210
7770
1092
150
740
85
95
88
105
Hot Water
380
390
120
100
315
100
620
1076
1100
250
250
150
400
510

FIG. 235.—Plan, Elevation, and End Views of Compressed Air Locomotive.

The engine is a single-cylinder type, 5-inch bore, 6-inch stroke, geared down 1 to 3 by wheel gearing on to the driving axle. The coupled wheels are 24 inches diameter. It can haul 90 tons on a level in fifteen trucks.

In order to get good results it is necessary to heat the air before it enters the engine. This is done by passing it through a vessel containing a large quantity of highly-heated water; this water imparts sufficient heat to expand the air down to atmospheric temperature in the cylinder, and the vapour carried by the air lubricates the cylinder.

STEAM FIRELESS LOCOMOTIVE

The Borsig Fireless Locomotive shown in Fig. 236 works with steam stored with water at a high temperature in a boiler shell; it is of standard gauge. Approximate weight in working order, 33,000 lbs. No danger of fire, as no sparks are thrown out. Explosion impossible, as after filling the boiler the steam pressure cannot, even through negligence, exceed the fixed limit. Can be employed inside buildings, even in the presence of inflammable goods. It is cheap to work, and the cost of maintenance small.

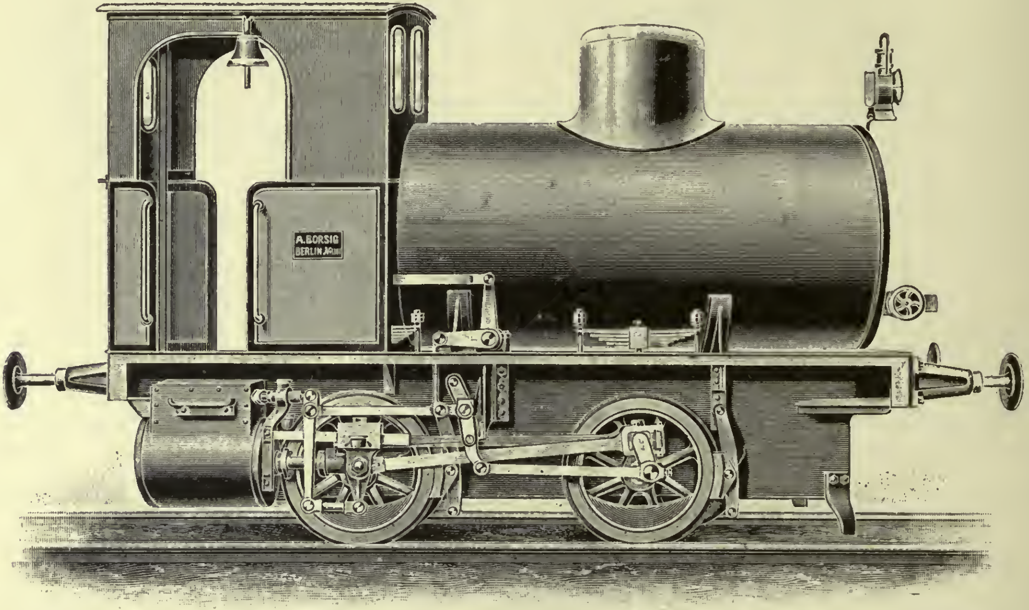


Fig. 236.—Steam Fireless Locomotive.

The steam reservoir with some water filled in is connected to a high-pressure steam supply. The steam condenses in the reservoir until the whole mass of water and reservoir attain very nearly a temperature and pressure equal to those of the steam supply boiler and condensation ceases. In working, the locomotive is operated through a reducing valve and the steam which condensed re-evaporates and runs the engine until the pressure falls to a low value.

The best fireless locomotive is an electric one, using storage electric cells to carry a supply of electricity. The cells should be carried in a compartment built of wood, and with ample ventilation, as metal employed in a storage battery compartment would soon be destroyed by the fumes given off in charging the cells, and these fumes should have a free and ready exit.

THE ELECTRIC LOCOMOTIVE—BALDWIN WESTINGHOUSE STANDARD TYPES

Electric locomotives may be divided into two classes—locomotives for surface haulage and locomotives for mine haulage.

Electric locomotives are coming to be extensively used for surface haulage. Aside from electrically driven cars for city streets, elevated structures, and interurban roads, numerous electric locomotives are now employed on short lines of railroads and for switching service at terminals, in industrial establishments, steel plants, lumber mills, iron furnaces, plantations, etc., and to a limited extent for handling heavy trains in railroad service.

It is evident that under suitable conditions, where the work is largely concentrated, a central power plant, transmitting electrical energy to a number of motors, is more economical than numerous steam locomotive units, which of necessity are not working under the conditions most favourable to economy. In localities where the cost of fuel is high, this economy will be most marked. The transmission of electricity at high potential for long distances has opened a wider field for electric locomotives in heavy railroad service. Electric transmission for 100 miles or more is not uncommon, and a larger radius for its commercial use may reasonably be expected.

For light railway service, for short branch lines, or for suburban freight or passenger traffic, where it is not convenient to equip the cars with motor-driven trucks, electric locomotives may be found economical; depending, however, on the length of the line, frequency of trips, speed, weight of train, and other conditions. A careful study of the requirements and facilities will, no doubt, in many cases lead to the adoption of electricity as a motive power.

In switching service for either heavy or light traffic, electric locomotives possess many important advantages, especially where electricity is employed for other purposes. At railway terminals and on docks, where the service is intermittent, they are particularly economical; when standing idle they consume no power and require little attendance. They likewise present marked economies for switching around iron furnaces, steel plants, etc., and are extensively used for such service. They are easily operated, not requiring a high-class engineer, while with a steam locomotive an engineer and fireman are essential. Their construction is of the simplest character, enabling repairs to be made easily and the cost of maintenance minimised, while their solidity enables them to withstand the severe shocks of rough usage. The compactness of their construction allows plenty of room for the operator, and makes them adaptable to restricted limitations of height and width.

The usual form of electric locomotive, having a motor geared to each axle, thus utilising all the weight for traction, is more economical in the consumption of power than the average steam locomotive hauling the dead weight of a tender and frequently an engine truck.

For haulage inside of manufacturing establishments, where the smoke and gases of steam locomotives are objectionable, and for lumber mills, plantations, etc., where the fire risk is excessive, electric locomotives are especially desirable.

Electric rack locomotives may be designed for any system of rack and gears, adapted to operate on any practicable grade.

Rack locomotives operated by steam are necessarily of considerable weight, being burdened by heavy machinery, a boiler, water and fuel. An electric locomotive, however, may be built with as little weight as substantial construction will permit; for successful operation the weight need only be sufficient to keep the gear wheels in the rack.

An electric locomotive can therefore be built to have an equal hauling capacity but of less weight than a steam rack locomotive. This is an important consideration where there are limiting factors in railroad construction, such as weight of rail, strength of bridges, etc.

For surface locomotives a large variety of motors are available, suitable for ordinary gauges. On exceedingly narrow gauges it is sometimes desirable to use motors of larger size than can be placed between the wheels. To meet these conditions, special designs have been prepared, patents pending, whereby motors of large capacity may be applied to any reasonable gauge by double transmission gears. The general arrangement of gears and suspension is illustrated (Fig. 237). The journals of the shaft carrying the intermediate gear run in boxes working in pedestals over the main journal boxes of the locomotive, and rigidly connected with them, permitting the locomotive to rise and fall on the axles without disengaging the gears. The locomotive is supported on springs in the usual manner. The motors are hung on the shafts of the intermediate gears as if they were the ordinary wheel axles, and the usual nose suspension employed. This

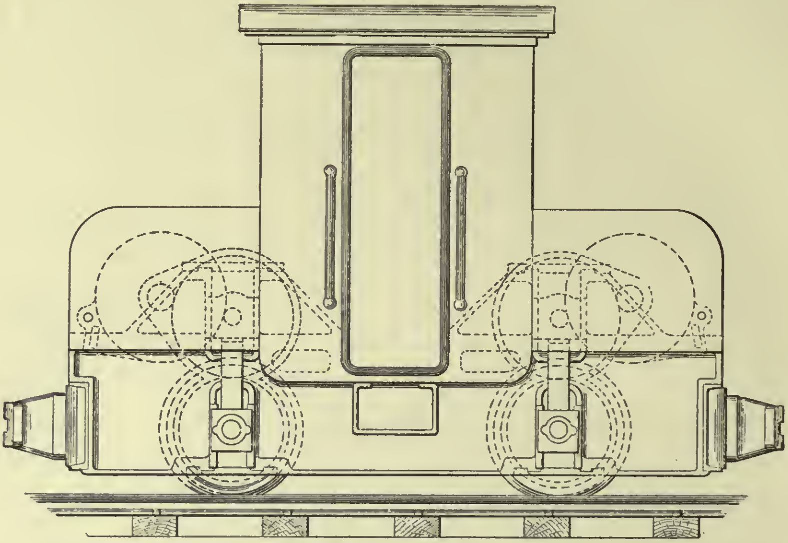


Fig. 237.—Elevation of Electric Locomotive.

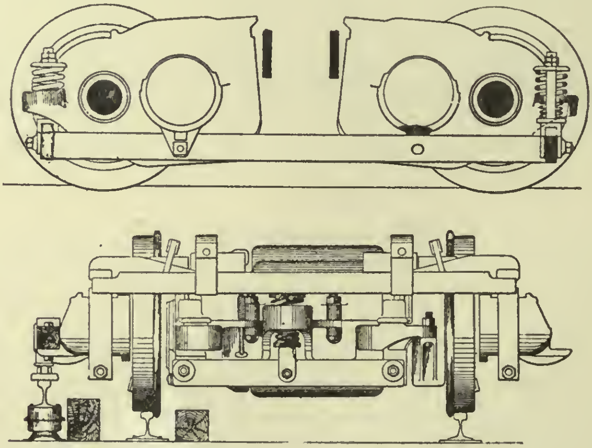


Fig. 238.—Electric Locomotive. Motor Suspension.

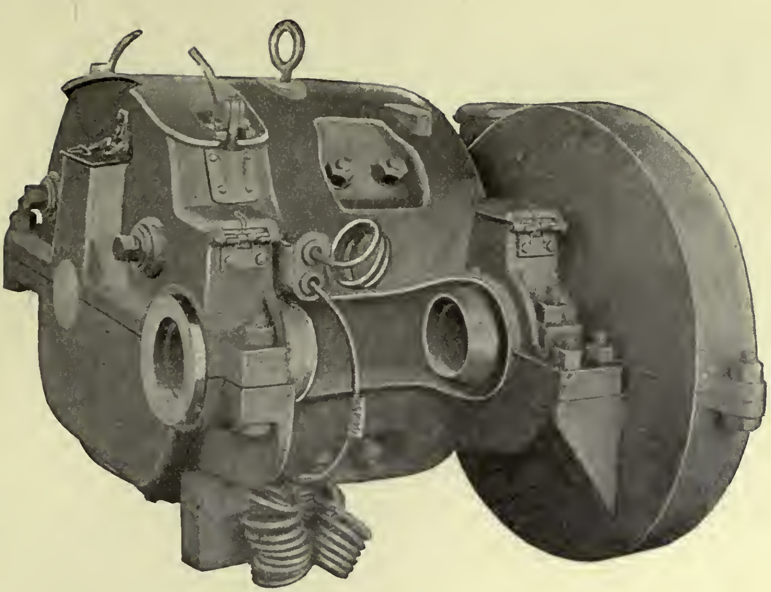


FIG. 239.—Motor of Electric Locomotive.

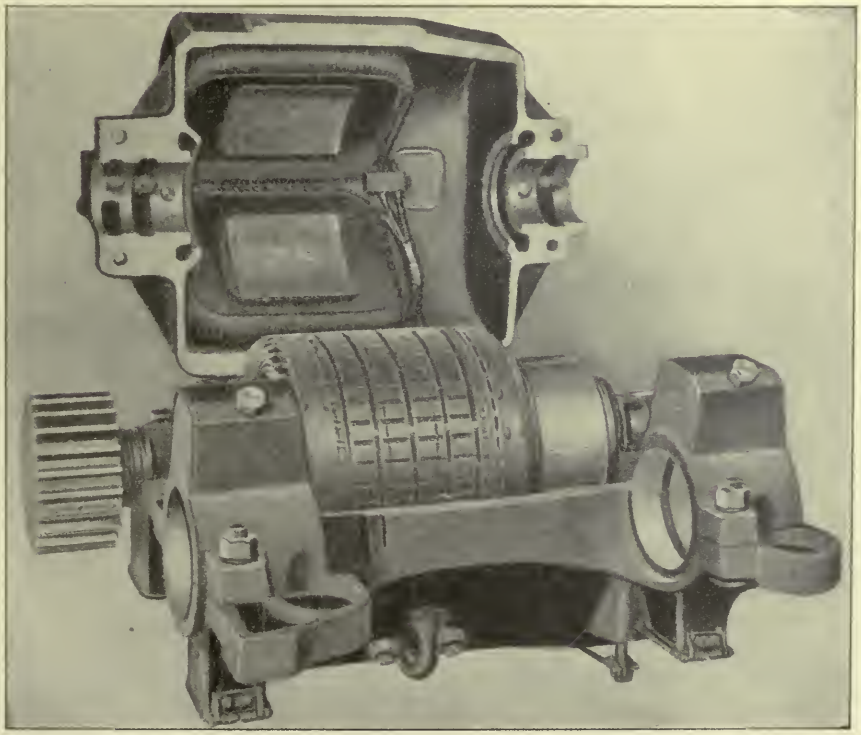


FIG. 240.—Motor of Electric Locomotive. Opened up.

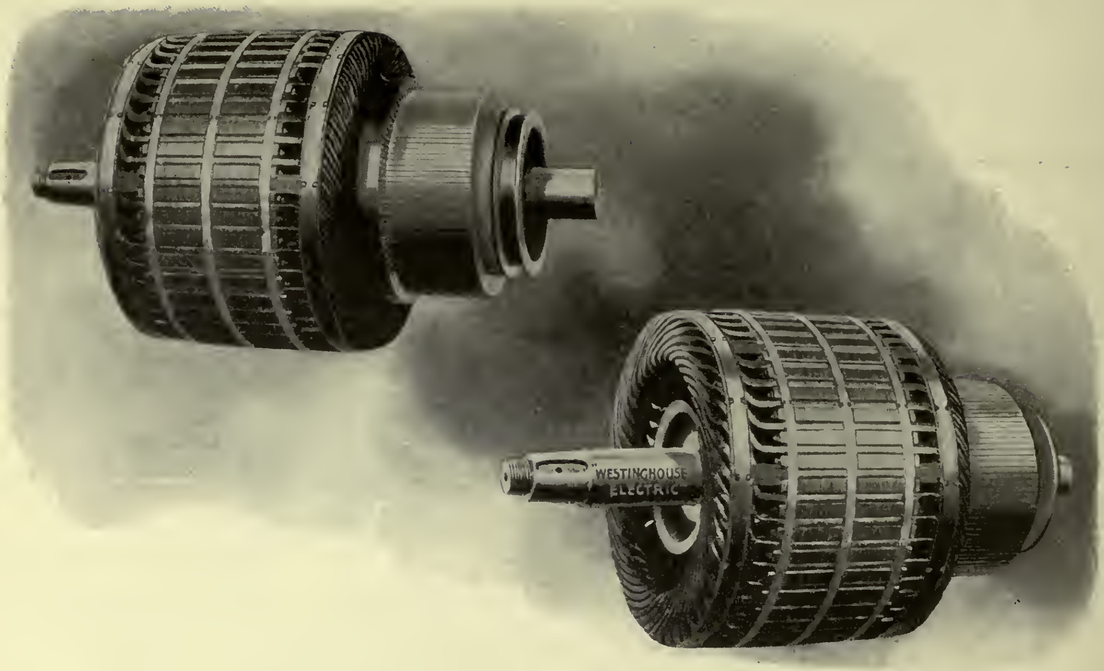

WESTINGHOUSE
ELECTRIC

FIG. 241.—Views of Armature for Electric Locomotive Motor.

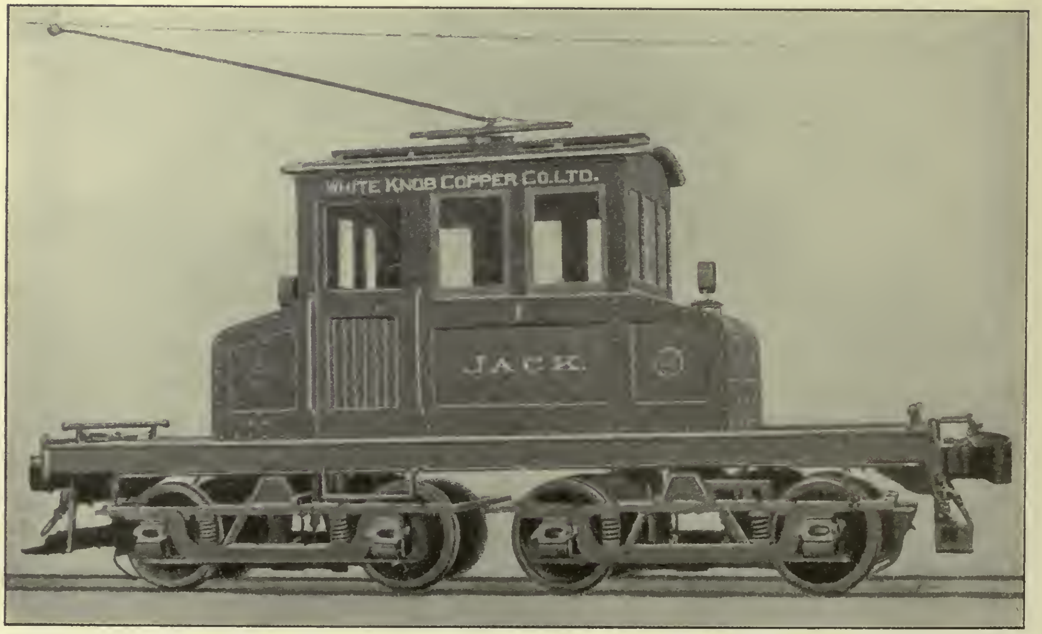

WHITE KNOB COPPER CO.LTD.
JACK.

FIG. 242.—Electric Mine Locomotive.

arrangement gives a motion to the motors exactly the same as if hung between the wheels with single gears.

Fig. 238 shows the cradle motor suspension, and at the left-hand side the line rail with the sliding shoe for picking up the current.

The motor here illustrated in Figs. 239 and 240 is a product of the Westinghouse Electric and Manufacturing Company, as in 1890 this company built the motor—the prototype of all successful modern railway motors. A radical departure was made in its construction from all previous designs. It possessed the following characteristics, ever since regarded as fundamental in all modern railway motors:—

1. Single reduction gears.
2. Slow-speed armature of small diameter.
3. Slotted-drum armature.
4. Two-circuit armature winding.
5. Four-pole field, each pole carrying a coil.
6. Machine-wound armature coils.
7. Hinged frames.
8. Spring suspension.

The motor is shown opened up in Fig. 240 showing the field magnet coils, the armature, and the pinion of gearing to the large wheel on the locomotive driving shaft, which passes through the two large bearings and so suspends the motor in gear.

Fig. 241 shows the armature from both ends, and Fig. 239 shows the motor closed up with gear case in place.

MINING HAULAGE LOCOMOTIVE

The general design is shown in Figs. 242, 244, and 245, illustrating examples of the standard types. The locomotive frame consists of heavy cast-iron side and end pieces, securely bolted together and kept square by machined joints and shoulders accurately fitted. These frame pieces are planed, top, bottom, and ends, to ensure perfect accuracy both in fitting up and in the interchangeability of parts. The pedestal caps are forgings made to template, and accurately fitted, so as to relieve the frame from breaking strains in case of severe shocks. The frame is placed either inside or outside of the wheels, in accordance with the limiting requirements of track gauge, power, and width of mine entries.

All larger sizes of locomotives are provided with separate shoes in the pedestals, to permit taking up excessive lost motion in the boxes, and to protect the frames from wear.

Heavy wooden doors and perforated metal plates are laid on top of the frames, thoroughly protecting all electrical parts, but also permitting perfect ventilation as well as access for inspection. End bumpers and coupling hooks are provided in conformity with the purchaser's requirements.

The driving wheels are of the best cast iron, with chilled treads, and are pressed and keyed on the axles, which are of steel, accurately turned for journal and motor bearings, and key seated for gear fit.

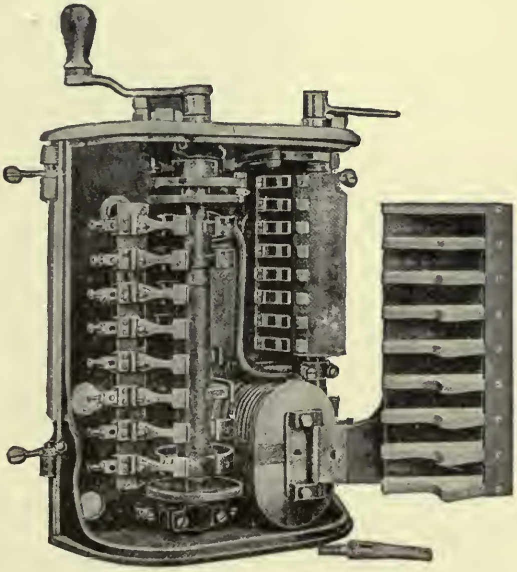


FIG. 243.—Series Parallel Controller.

The journal boxes are of ample dimensions, and have bronze bearings with oil cellars for sponging, as in steam locomotive practice.

The "series parallel" control is the more economical, as less energy is dissipated in the resistance. For such work as yard shifting, however, the "rheostatic" is generally preferable, as the troubles due to slipping of wheels are reduced, owing to the fact that with two motors connected in series, if the wheels driven by one motor slip, the current through the other motor falls off, and the tractive effort exerted by it is consequently reduced; while with motors connected in parallel, if one slips its wheels, the tractive effort exerted by the other is increased, which tends to a certain extent to make up for the slip. The series parallel controller designed for handling two 500-volt 50 horse-power motors is illustrated in Fig. 243.

In special cases a switch is provided with "rheostatic" control, by means of which the motors can be thrown in series if desired.

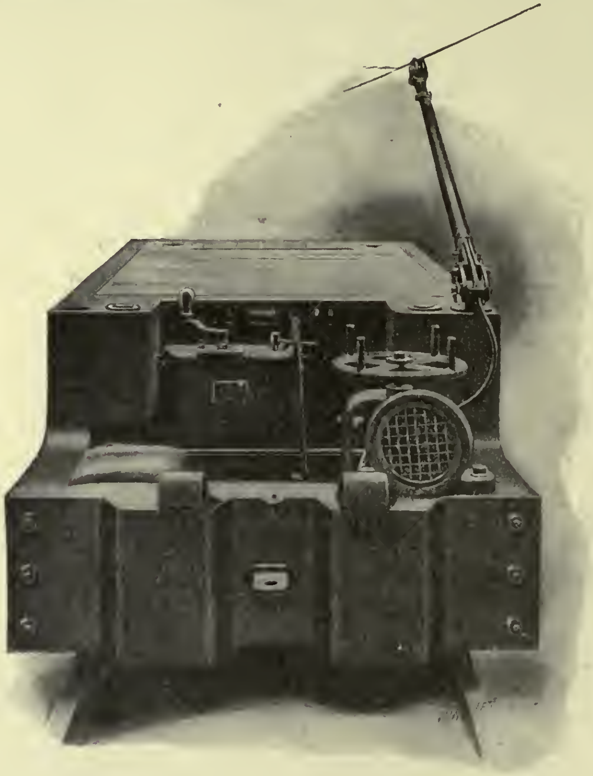


FIG. 244.—End View of Electric Mine Locomotive.

Controllers are provided with a magnetic blow-out device, which reduces to a minimum the arcing at fingers and contacts.

Two standard forms of resistance are manufactured for locomotives—the "iron-clad cell" and the "grid" diverter. The iron-clad cell diverter consists primarily of a strip of sheet metal wound in a spiral form on an iron cell with mica interposed between the layers.

The standard mine locomotive is shown complete in side view (Fig. 245), and in end view (Fig. 244).

The trolley pole is specially designed for mining service, is reversible, and can be placed in a socket in either side of the frame. It automatically adjusts itself to the varying heights of trolley wire. It is thoroughly insulated to prevent shocks to the operator, and the current connections are made by insulated cable.

Fig. 246 illustrates an electric locomotive built by Messrs. Dick, Kerr, & Co. Ltd., to run on a track gauge of 18 inches, the wheel base being 44.314 inches. It is propelled by a single motor geared to the driving wheels through a double reduction gear, the ratio of the first reduction being 14 to 53 and of the second 21 to 55, making a total reduction gear ratio of about 1 to 10. The pinion on the armature spindle is made of raw hide, the rest of the gears being cast iron with machine-cut teeth. The four driving wheels are also of cast iron, having a diameter of 21 inches pressed on to $2\frac{3}{4}$-inch axles. All bearings are provided with oil lubrication, the oil being fed through pads slightly rubbing on the shaft. Channels are provided for the oil to run back in the oil chamber again after being used. The motor, which is series-wound type, is rated to give an output of 15 horse-power at a terminal pressure of 220 volts, the rating being based on standard railway practice; that is, after one hour's run at full load the tem-

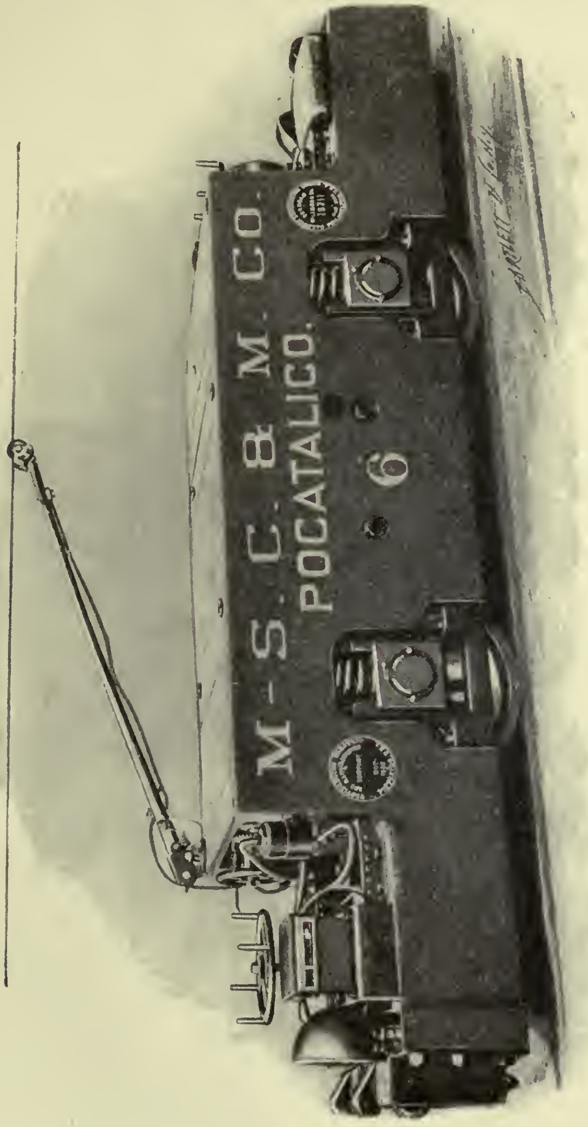


FIG. 245.—Electric Mine Locomotive.

perature of the motor winding shall not exceed a rise of 70° C. above the temperature of the surrounding air. The rheostat controller is of the Dick-Kerr standard railway type, and is designed to control the motors at six different speeds. The trolley is of the sliding bow type, with a double-acting spring which can readily be adjusted to give the required pressure on the trolley wire. The sliding is made of soft white metal, which can

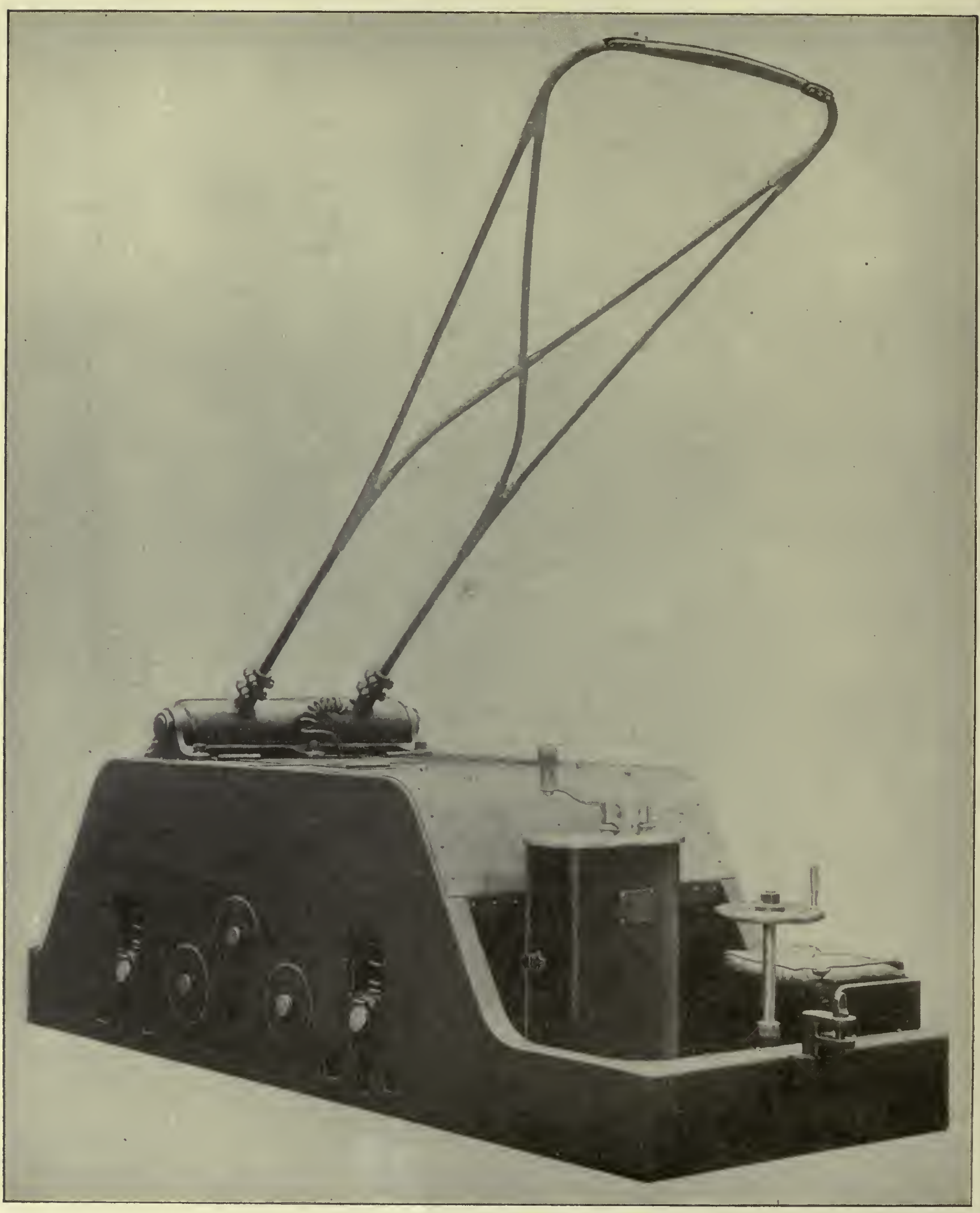


FIG. 246.—Narrow-Gauge Electric Locomotive.

easily be renewed when worn out. The braking is controlled by an ordinary hand brake. The total weight of the locomotive is 5068 lbs.

ELECTRIC LOCOMOTIVE FOR GOODS TRAFFIC

The illustrations (Fig. 247 to 251) show the construction of the electric locomotives built at the works of the Brush Electrical Engineering Company Ltd. for the North-Eastern Railway Company's system at Newcastle, to the order of the British Thomson-Houston Company Ltd.

These electric locomotives are the largest yet built in this country, and were designed to be capable of hauling a 300-ton train on the level at a speed of 14 miles per hour, or of starting a train of 150 tons on a grade of 1 in 27 under all conditions of weather, and of running such a grade at a speed of 9 to 10 miles per hour. Under test they have, however, considerably exceeded the guaranteed performance both as regards speed and tractive effort.

The principal dimensions are as follow:—

Weight	50 tons.
Gauge	4 feet 8½ inches.
Length over buffers	37 ,, 11 ,,
,, over headstocks	35 ,, 0 ,,
,, of central cab	9 feet 0¼ inch.
Centre of trucks	20 ,, 6 inches.
Wheel base of each truck . . .	6 ,, 6 ,,
Extreme width	8 ,, 8 ,,
Width over side sills	7 ,, 10⅝ ,,
,, over cab	7 ,, 6¼ ,,
Height from rails to top of cab . . .	11 ,, 9 ,,
,, from rails to top of floor . . .	4 ,, 3¾ ,,
,, of cab (clear)	7 ,, 3⅛ ,,
Diameter of wheels	3 ,, 0 ,,
,, of axles at centre . . .	6⅜ inches.
,, of axles at wheel seats . .	7 ,, 28 ,,
,, of journals	6 ,,
Length of journals	10 ,,

The British Thomson-Houston Company Ltd., to whose order, as already stated, the locomotives were built, supplied the electrical equipment, and erected it at the Brush Company's works, thus enabling the locomotives to be delivered to the Railway Company in running order, with the exception of a few parts which were readily fixed after reaching Newcastle, and which it was necessary to remove owing to transit difficulties.

This equipment consisted of four G.E. 55 type motors with two turn armatures and 3.28 gear ratio, one motor being mounted on each of the four axles. The control is on the Sprague-Thomson-Houston multiple unit system, the principle of operation of which is well known.

The air compressor for the brake gear is a British Thomson-Houston electrically driven C.P. 14 compressor, which is hung underneath the frame, and is capable of compressing against 90 lbs. pressure with a cylinder displacement of 20 cubic feet per minute. The locomotive operates over sections fitted with an overload line and third rail, and is equipped with a sliding bow trolley, in addition to the shoes, which reverses automatically according to direction of travel, and can also be reversed and lowered from the cab by means of a hand-wheel actuating worm gear.

The trucks are of the plate frame type, with angle steel stiffeners and corner

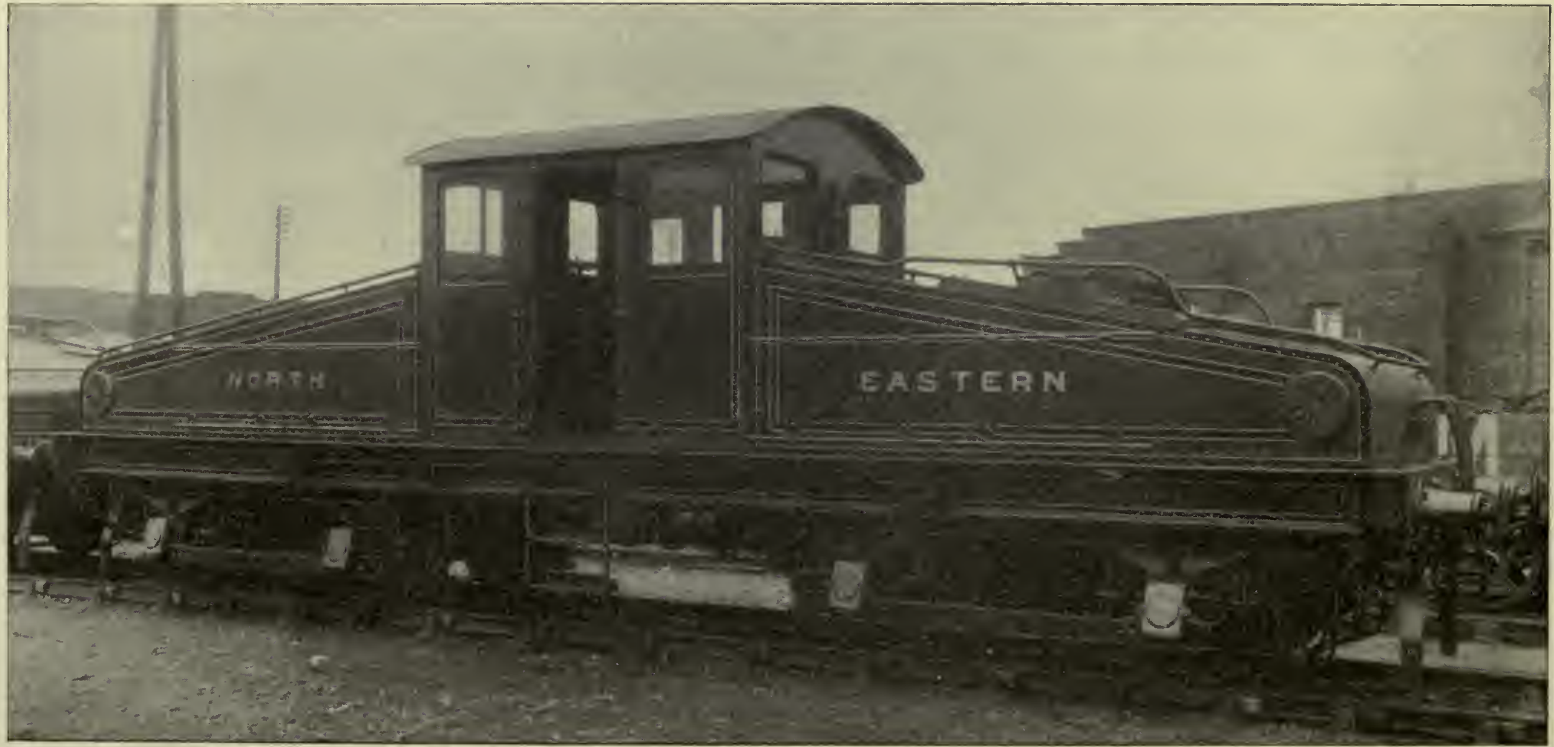

NORTH
EASTERN

FIG. 247.—Electric Railway Locomotive.

gussets. The swing bolster is supported on two nests of coiled steel springs, and is fitted with wearing plates, pivot plates, and side bearings of cast steel. The axle boxes are also of cast steel, and are provided with wings to carry the oak collector beams. The journal brasses are babbitt lined, ample provision having been made for lubrication and for the exclusion of dust. The wheels have rolled steel tyres 5½ inches wide by 2½ inches thick, shrunk on to cast steel disc centres.

The main frame is built up of heavy rolled steel sections, with ballast blocks of cast iron to give the necessary adhesion to the locomotive. The side soles are girder section 12 by 6 inches, weighing 54 lbs. to the foot, and the longitudinals are of channel section 8 by 3½ by ⅝ inches, with headstocks 15 by 4 by ½ inches, also of channel section. To the headstocks are bolted oak buffer beams, 15¾ inches deep by 8 inches wide. To prevent the frame from racking heavy gusset plates stretch across the frame from side to side; those on the bolsters being 3 feet wide by ¾ inch thick, and those at the headstocks are 20 inches wide by ½ inch thick. Gusset plates 15 inches wide are fixed at the channel section cross bars. The bolsters are each built up of two girders 6 by 4 by ½ inches, cut away at the ends to fit under the side soles, and riveted to the main gusset plate; an under gusset 17 inches wide by ¾ inch thick is riveted to the girders.

The cab is constructed of ⅛-inch steel plates riveted to steel angles, and is built in three sections, two sloping ends and a central driver's cab. The floor is of non-flammable timber, 1⅞ inch thick. Under the sloping ends the Westinghouse air brake reservoirs, the sand hoppers, the contactors, reverser, rheostats, and motor compressor are fixed.

The driving and control apparatus in the central cab is in duplicate, and is placed in positions that are convenient to the driver when facing the direction in which the locomotive is travelling.

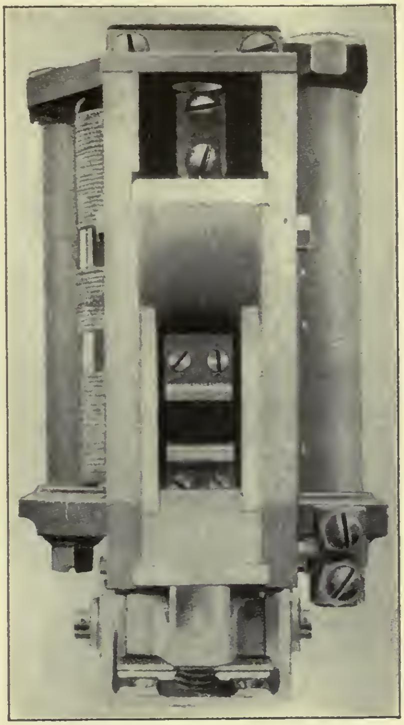


FIG. 248.—Contactor.

Owing to the comparatively heavy gradients of the line over which these locomotives work, careful attention has been given to the brakes. Blocks are fitted to each side of each wheel, and with the specially strong foundation rigging a pressure of from 70 to 80 per cent. of the total weight of the vehicle may be applied to the wheels, either from air brake cylinder which is fixed underneath the main frame, or from the hand wheel situated in the centre of the driver's cab.

The Sprague-Thomson-Houston multiple unit control system is used throughout. This method has been frequently described, but an account of it as applied to the North-Eastern trains may be of interest. Beneath each motor coach are fixed a number of electrically operated switches called contactors (see Fig. 248), for making necessary connections with the motors and for cutting in and out the resistances step by step. The contactors are actuated by current derived from a nine-wire multiple cable, which runs from end to end of each motor coach, and is fitted with suitable coupling devices at each end. The trailer coaches also have a multiple cable with couplings. In this way the train, when made up, no matter how long, has a continuous nine-wire cable from one end to the other, and by letting current into any wire of this cable at any point in the train the corresponding electrically operated contactors on all the motor coaches are simultaneously actuated, and thus the necessary combinations of motors and resistances are made on each of the coaches throughout the train.

The controller, which at the will of the driver introduces current into the nine-wire cable, is called a master controller, and it is shown in Fig. 249. To prevent the operating cylinder from moving too rapidly, its speed is regulated by a limiting device, and the rate of current input is regulated by a current relay in series with the motor circuit, which closes a local circuit, locking the master controller against movement until the accelerating current has fallen sufficiently to release the cylinder for movement to the vent notch.

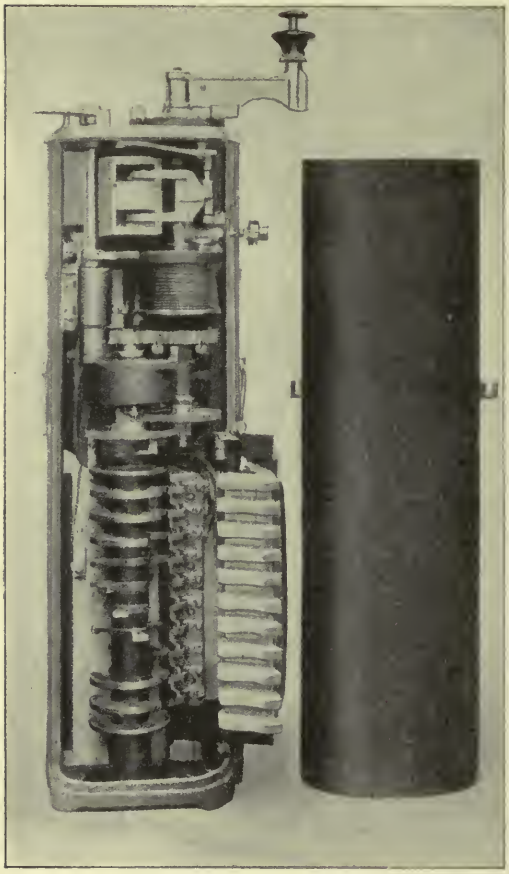


Fig. 249.—Master Controller.

The following further points in reference to this system of operation will be of interest, particularly to those who have not previously studied the method. A view of the master controller is given in Fig. 249, while one of the contactors is shown in Fig. 248. The main motor current does not pass through either the master controller or the train control cable, these parts carrying only the current which operates the contactors. Each motor car collects its own motor current by means of its collector shoes, and the current for operating the contactors of all motor cars in the train is drawn from the collecting device through the master controller on the car from which the train is operated. The position of the master controller handle indicates to the driver the exact position of all the motor controllers on all the cars. The rate of movement of the motor controllers, and consequently the amount of current taken by all the motors, are under his immediate control, just as it is with an ordinary hand operated controller. If the train breaks in two the current is automatically and instantly cut off from the motors on that part of the train which is not under the control of the motor-man, while his ability to control the front part of the train is not affected. For reversing the motors, the master controller is provided with a separate reversing handle, and a mechanical locking device prevents this handle from being thrown over unless the main handle is in the off position.

These controllers are provided with an automatic attachment whereby current is instantly cut off throughout the train should the driver remove his hand from the operating handle. This device ensures the safety of the passengers in case of injury or accident to the driver. In addition to this, there is provided in each master controller an attachment which also applies the air brake if the motor-man releases the power handle. This attachment is mechanically interlocked with the current cut-off device, ensuring a brake application should the motor-man release the handle while the train is coasting with the master controller at the "off" position. Thus if, for any reason, the motor-man is incapacitated or compelled to release the power handle of the master controller, the power is instantly cut off from all motors on the train, and the brakes are applied to all cars on the train.

The control operating current at 550 volts potential is about 2.5 ampères per car for an equipment of two 200 horse-power motors, and the total weight of the control apparatus for this equipment is approximately 2200 lbs.

It will be understood that the thirteen contactors of each car are electrically equivalent to the cylinder of an ordinary controller, by which the necessary rheostatic and motor combinations are made. Each contactor consists of a movable arm carrying a finger which makes contact with a fixed terminal finger, and a coil for actuating the arm when supplied with current from the master controller. The motor circuit is closed only when current is flowing through the coil. Gravity, combined with a spring action of the finger, causes the contactor to open immediately the master controller circuit is interrupted.

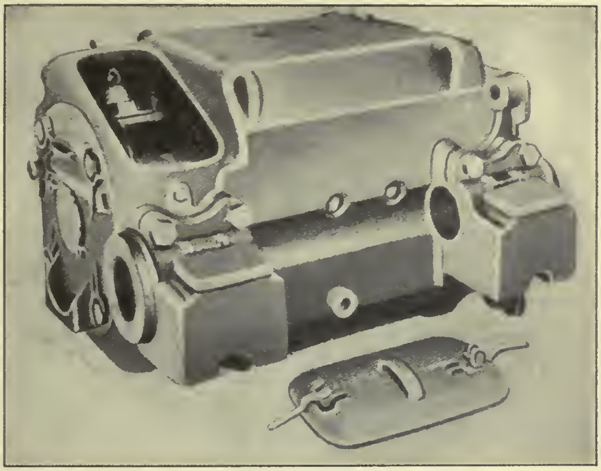


FIG. 250.—Motor of Electric Locomotive.

The motor is shown in Fig. 250. The bearings are liberal in dimensions, and thorough means of lubrication is provided. The commutator end bearing is $3\frac{3}{4}$ inches in diameter, by $6\frac{7}{16}$ inches long, and the pinion end bearing is 4 inches in diameter by 10 inches long; the axle bearings are $10\frac{3}{4}$ inches long. The armature has a series drum barrel winding, and its conductors are made of copper bars, specially constructed for preventing eddy currents. The conductors are connected up in 39 quintuple coils, each consisting of five single coils of one turn each. The conductors are separately insulated with mica in sets of five, the set as a whole having an outside protection insulation of mica, with an external covering of specially prepared tape, which has high insulating qualities, and affords protection against both mechanical injury and moisture. This method of insulation renders the windings semi-fireproof, and able to withstand a high temperature without injury to the insulation. The conductors are soldered directly into ears forming a part of the commutator segments. At the back of the armature the top and bottom bars are connected with tinned copper clips riveted and soldered, but easily removable if desired. The conductors are held in the slots by tinned steel wire bands embedded in the core. The commutator contains 195 segments of the best hard drawn copper, insulated entirely with mica, and clamped with mica cones on cast steel shafts. There are four field coils wound on metal spools, which are held in place by the laminated pole pieces. The spools are wound with strip copper thoroughly insulated from the spools with mica, asbestos, and cloth, and between turns with asbestos. This construction makes a spool practically fireproof and impervious to moisture. It is not easily injured mechanically, and is specially well adapted to radiate heat. The motor leads to the car wiring are protected by flexible metallic armouring, screwed into a brass bush, tapped into the flanges of the spools. The spider of the armature is so arranged that the armature becomes practically a centrifugal blower when at full speed. The insulation on the field poles is subjected to a high potential test of 4000 volts alternating current, and the completed armature to a test of 3000 volts between the winding and the core. The insulation of the commutator between the segments and the shaft meets a test of 4000 volts, and between the segments 400 volts.

Fig. 251 shows a plan of the truck, with the motor and gearing.

PETROL LOCOMOTIVE

This type of locomotive is designed for use on all kinds of light railway track, tramways in large factories, light junction railways, and mining and quarry equipments.

The locomotive is made in several sizes, to suit the particular requirements pertaining to individual cases, the gauge, wheel base, height of buffers, loading gauge, etc.

The advantages over steam are obvious—running expenses are less, there is no visible exhaust, and by the use of a large size muffler or exhaust box the running of the motor itself is very quiet. The utilisation of an internal combustion engine for this type of work of course does away with the necessity of keeping engines in steam when not in use.

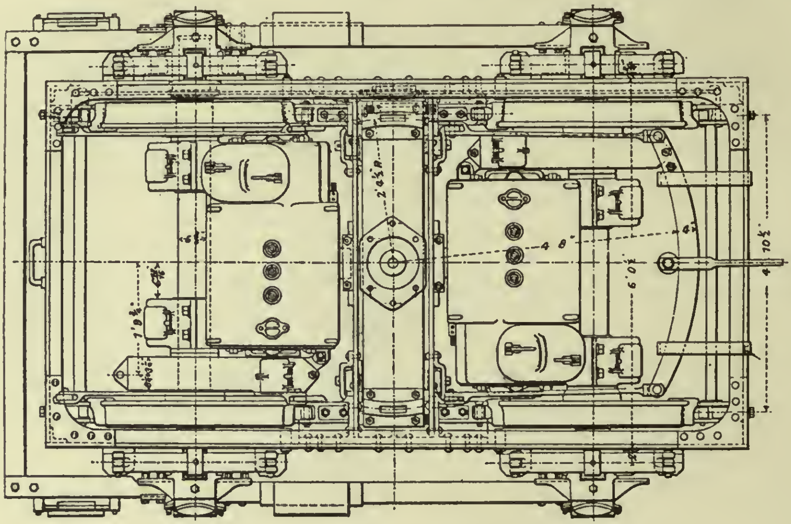


FIG. 251.—Truck of Electric Railway Locomotive.

For light railway work, where the service is almost entirely intermittent and irregular, it is of great practical importance not to be consuming fuel when out of service. A petrol engine can, of course, be started at a minute's notice when the locomotive is required for work.

A locomotive of this description possesses all the advantages claimed by the makers of light railway electric installations, and in addition to that requires no expensive permanent way, fixtures, nor the establishment of an elaborate central station.

Engines of this description are coming into use where a cheap, reliable, and variable service is required.

A general arrangement elevation of the "Wolseley" type of locomotive is shown (Fig. 252). It is fitted with a standard type "Wolseley" horizontal petrol motor of sufficient power. This engine is equipped with a heavy fly-wheel, to render it capable of starting readily with heavy loads on railways and tramways.

The engine is constructed throughout on the lines adopted by the "Wolseley" Company for their motor car engines, with this important exception, that the engine is very much more substantial and therefore heavier type. The use of aluminium has been entirely eliminated.

The bearings are of ample size, and every provision has been made to ensure the

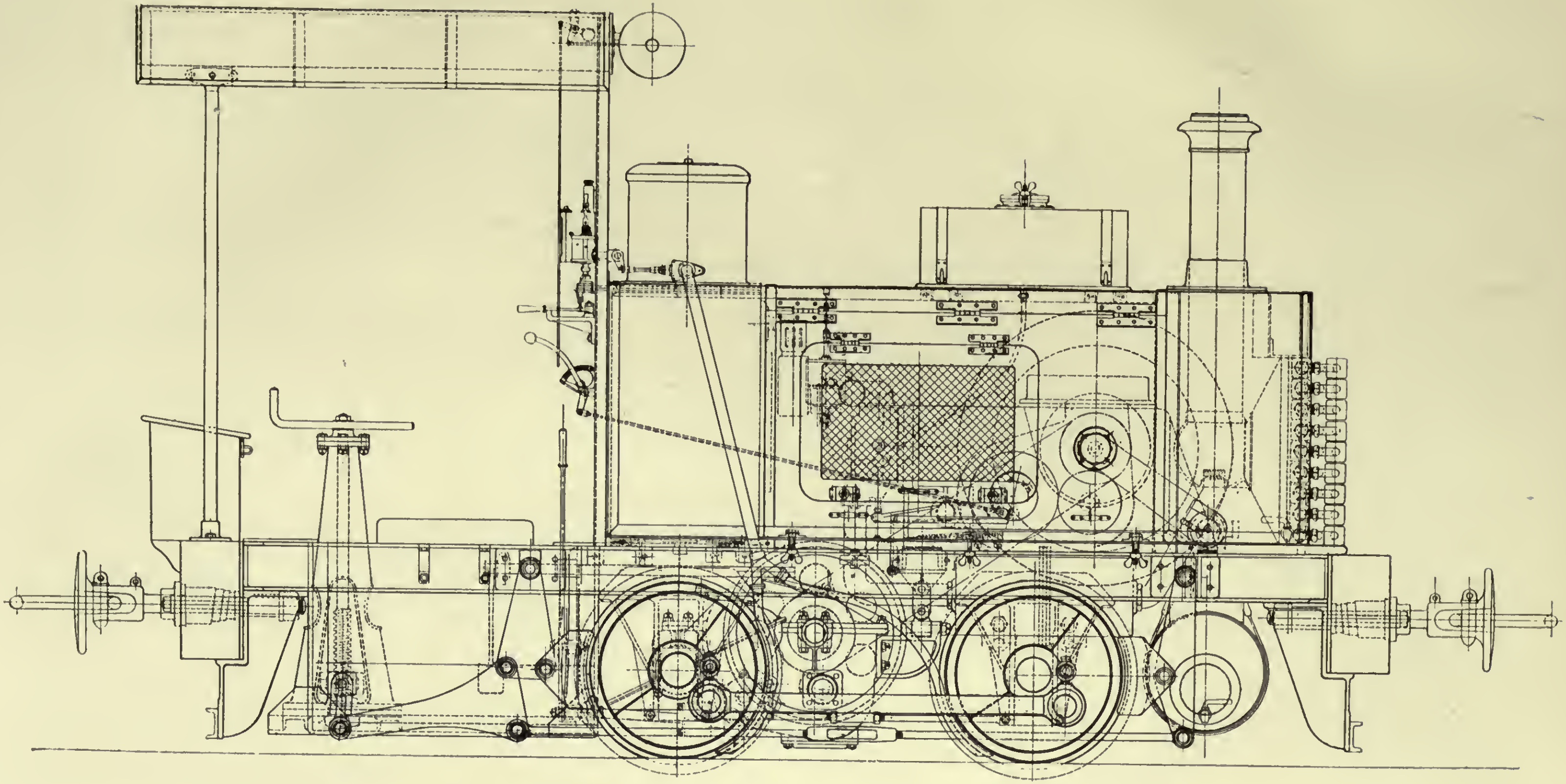


FIG. 252.—Petrol Railway Locomotive. General Arrangement Elevation.

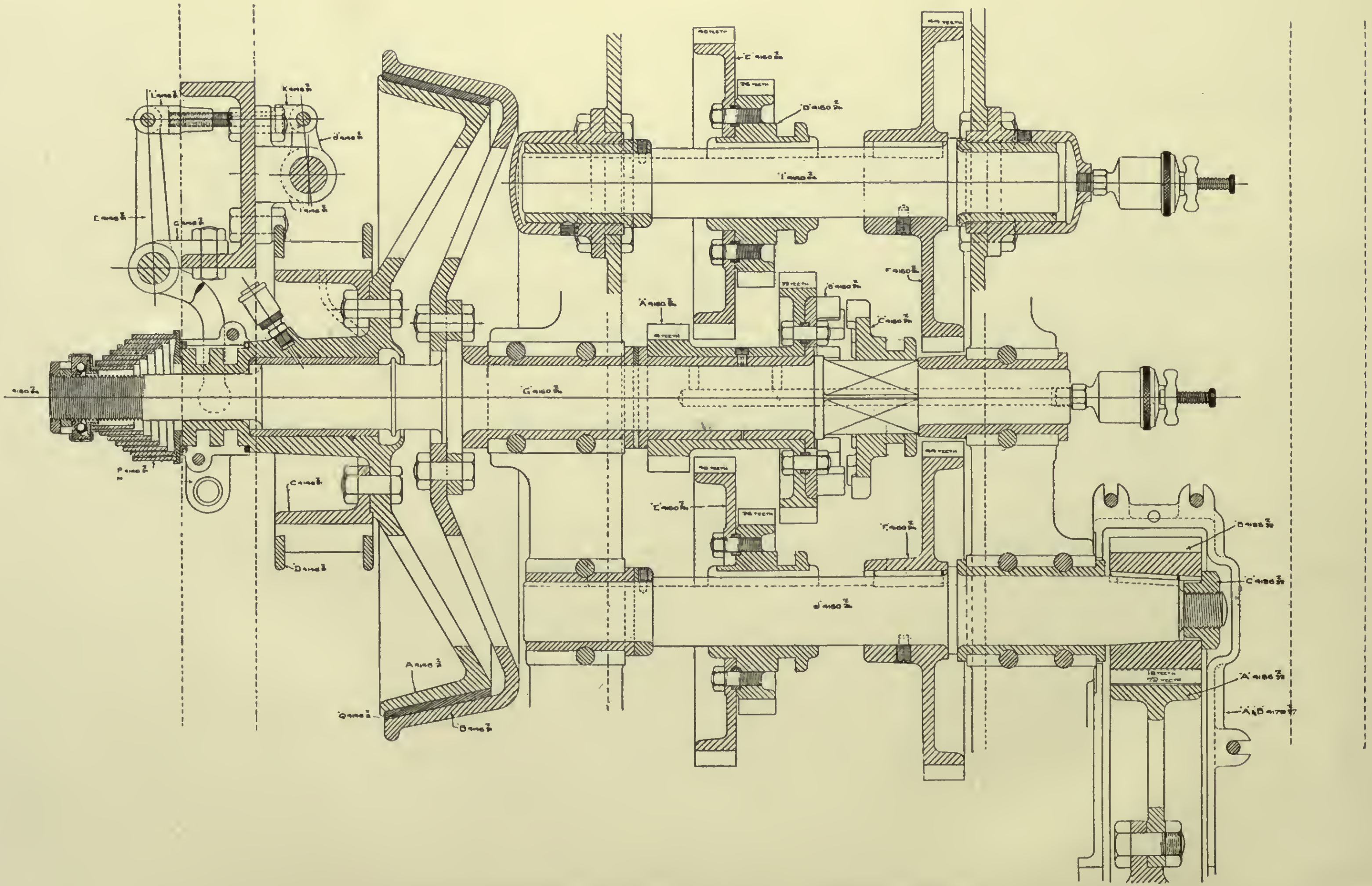


FIG. 253.—Development of Gear Box for 6 × 7 × 2 Petrol Locomotive.

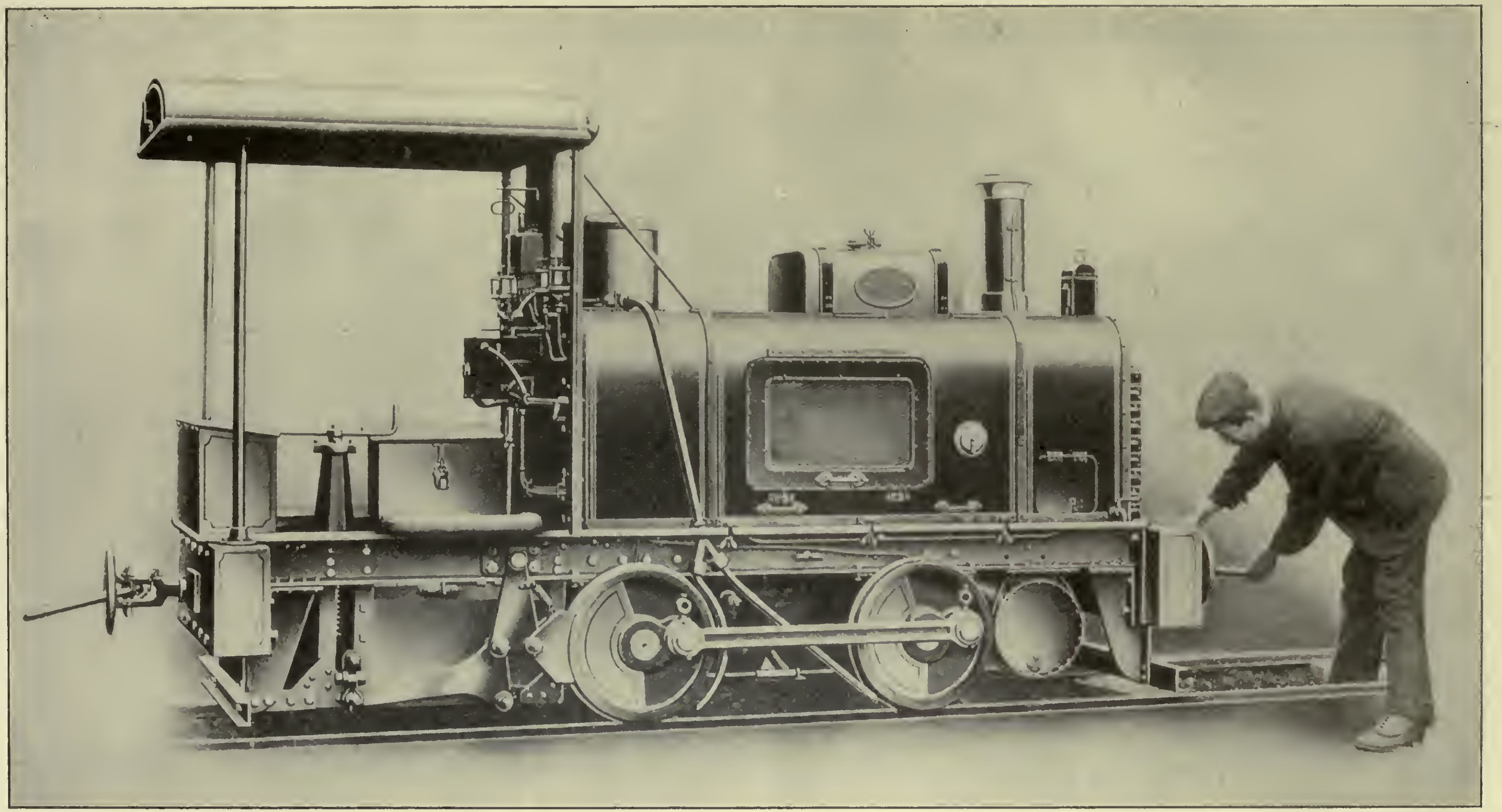


FIG. 254.—Petrol Railway Locomotive.

regular running of these engines for a very long while. For all ordinary purposes the locomotive is fitted with four driving wheels coupled, of a wheel base sufficient to enable it to negotiate the smallest curves on the tramway or railway on which it is to run.

The frame of the locomotive is of stout channel steel, stiffly braced by similar transverse members with ample gusset plates. The horn blocks are of cast steel, and bolted direct to the frame. In the smaller types of engines these horn blocks contain spring boxes for locating the spiral springs on which the engine is supported. For larger sizes a combination of laminated and spiral springs is adopted.

The power is taken from the motor by means of a "Renold" silent chain (high speed). One chain wheel for this drive is mounted on the crank shaft of the motor, immediately outside the fly-wheel, the other one being carried on the first motion shaft of the specially constructed gear box. This same shaft carries a powerful friction clutch of suitable design, which is conveniently operated from the driver's seat.

The gear box (Fig. 253) has special features. It is supported by universal nose suspension on the forward end, and on two ample bearings on the rear axle itself. This renders the box entirely self-contained, and enables a perfectly rigid drive to be obtained for the final gear, which consists of a broad tooth spur pinion-wheel carefully cased in, and running in grease. It will be readily seen, therefore, that both the engine and gear box are entirely self-contained, and unaffected by any stresses set up due to unequal twisting of the main frame.

This is an extremely important consideration for light railway work, where locomotives of this type are liable to be subjected to extremely rough handling during shunting operations, etc.

The "Renold" chain provides an extremely flexible drive between the engine and gear box.

The change of speed is effected by means of sliding gears and a positive clutch.

The whole gear box is a very substantial job, and the gears are specially designed for long life.

The change-speed gear necessary to operate the two speeds forward and one reverse is mounted on the box, and the necessary operating lever is connected thereto by means of a universally jointed shaft. The forward speeds are approximately 3 and 8 miles per hour at normal engine speed. The change speed is effected by means of sliding gears and a positive clutch, the final reduction in the gear box being by ordinary spur-wheels.

A large ballast tank is supplied, and a high-speed pump on the engine keeps the cooling water circulating. The action of the exhaust through the chimney also keeps a current of cold air circulating all round the engine.

The electric ignition is of the magneto high-tension type. The use of batteries is not recommended for this type of work. The petrol tank is provided to carry 10 gallons, enabling the engine to run at full power for ten hours. A large sand box is fitted, and kept dry by the circulation of the warm water from the engine round it. Hand-actuated sand pipes are fitted to all four wheels. A powerful brake is fitted to each wheel, and is actuated from the driver's seat by a wheel and screw arrangement. The brake blocks are of wood, and are easily adjustable when necessary.

The complete view is shown in Fig. 254.

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